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May et al.

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(54) **ORTHOPEDIC FIXATION DEVICE, SYSTEM AND METHOD**

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A61B 17/68 (2006.01)

(52) **U.S. Cl.**

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(58) **Field of Classification Search**

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See application file for complete search history.

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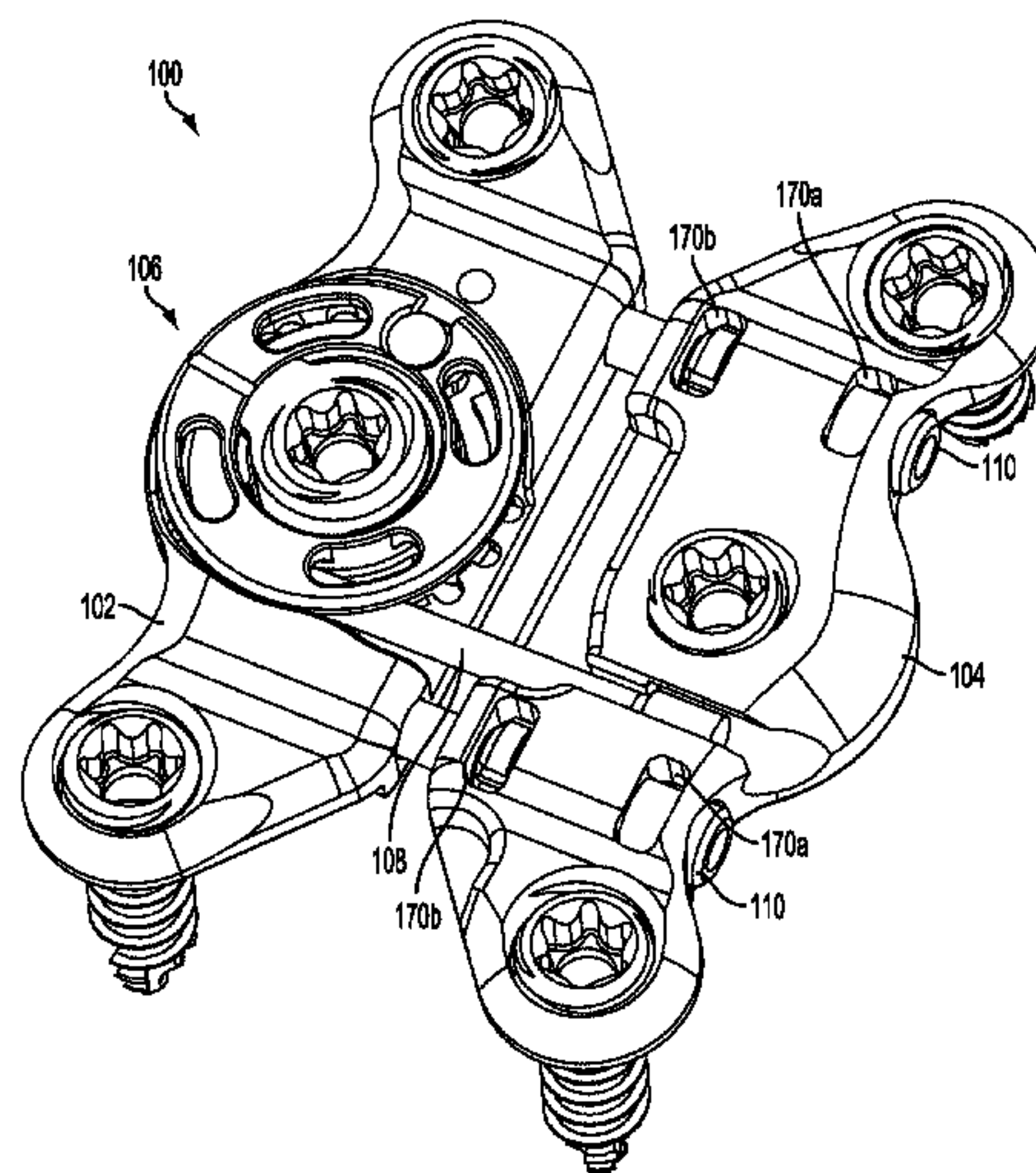
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(57) **ABSTRACT**

An implantable fixation device for rejoining opposed portions of a separated bone. The device including two corresponding plates that are configured to be aligned and coupled to a bone, such as a sternum, pre-resection of the bone or prior to cutting/separating the bone. The placement of the corresponding plates provides a gap between the edges of the plates that face one another allowing for and guiding a cutting tool for separating the bone. After the bone has been cut and the desired surgical procedure performed, the plates also assist in realigning and fixation of the bone portions. At least one plate includes a ratchet mechanism that is configured to tighten a locking element and draw the two plates together and into alignment with one another.

24 Claims, 17 Drawing Sheets



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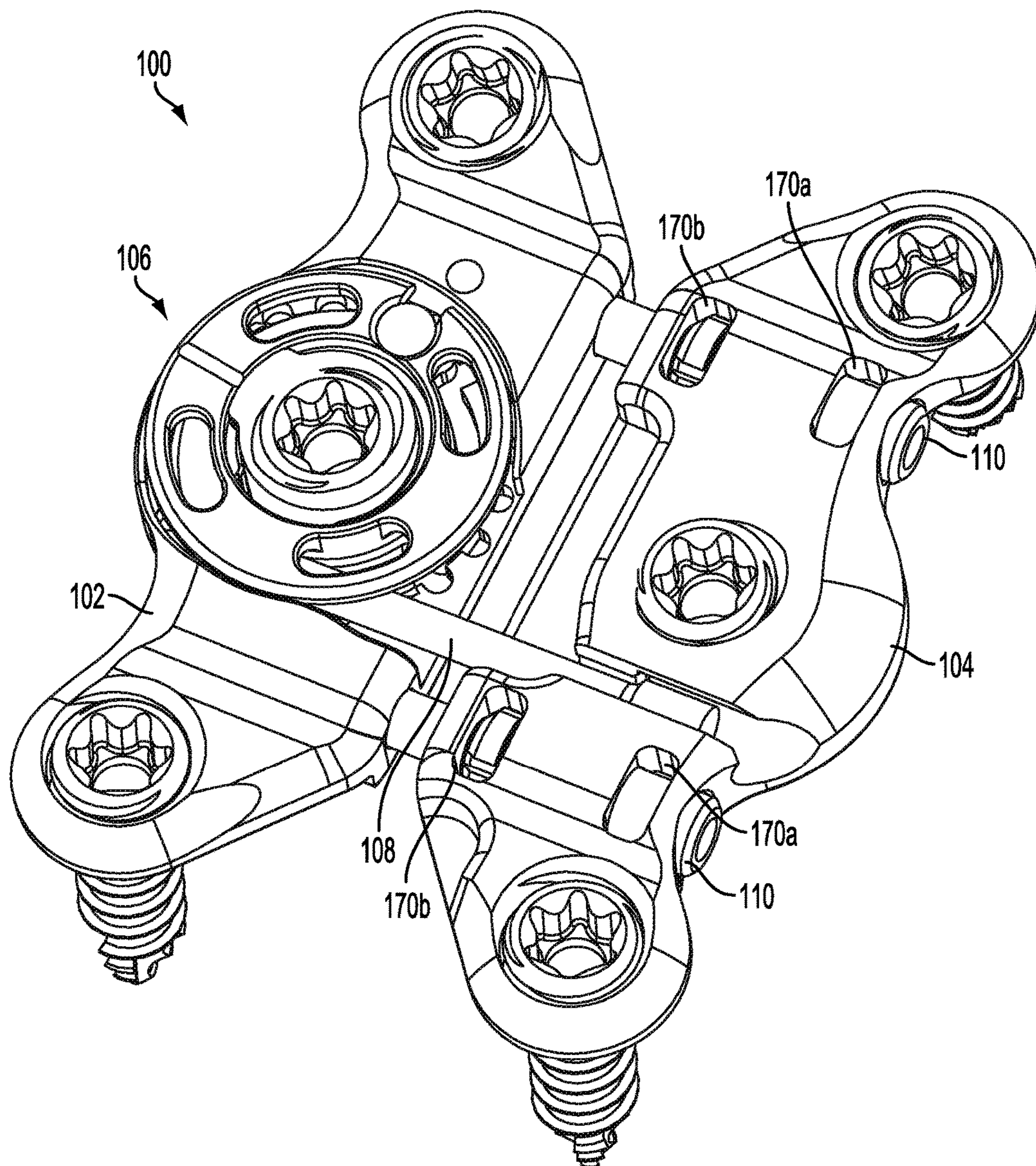


FIG. 1

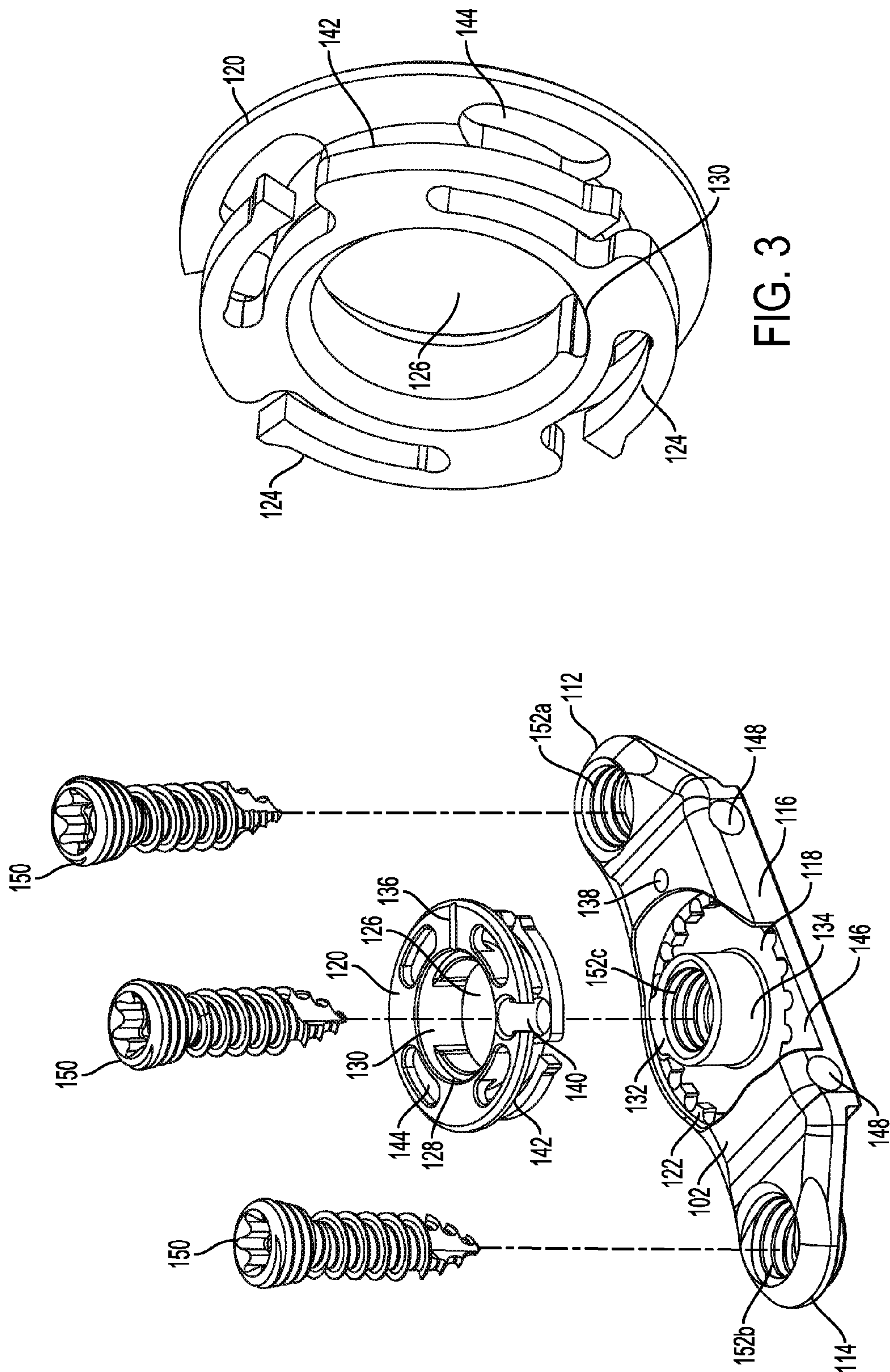


FIG. 2

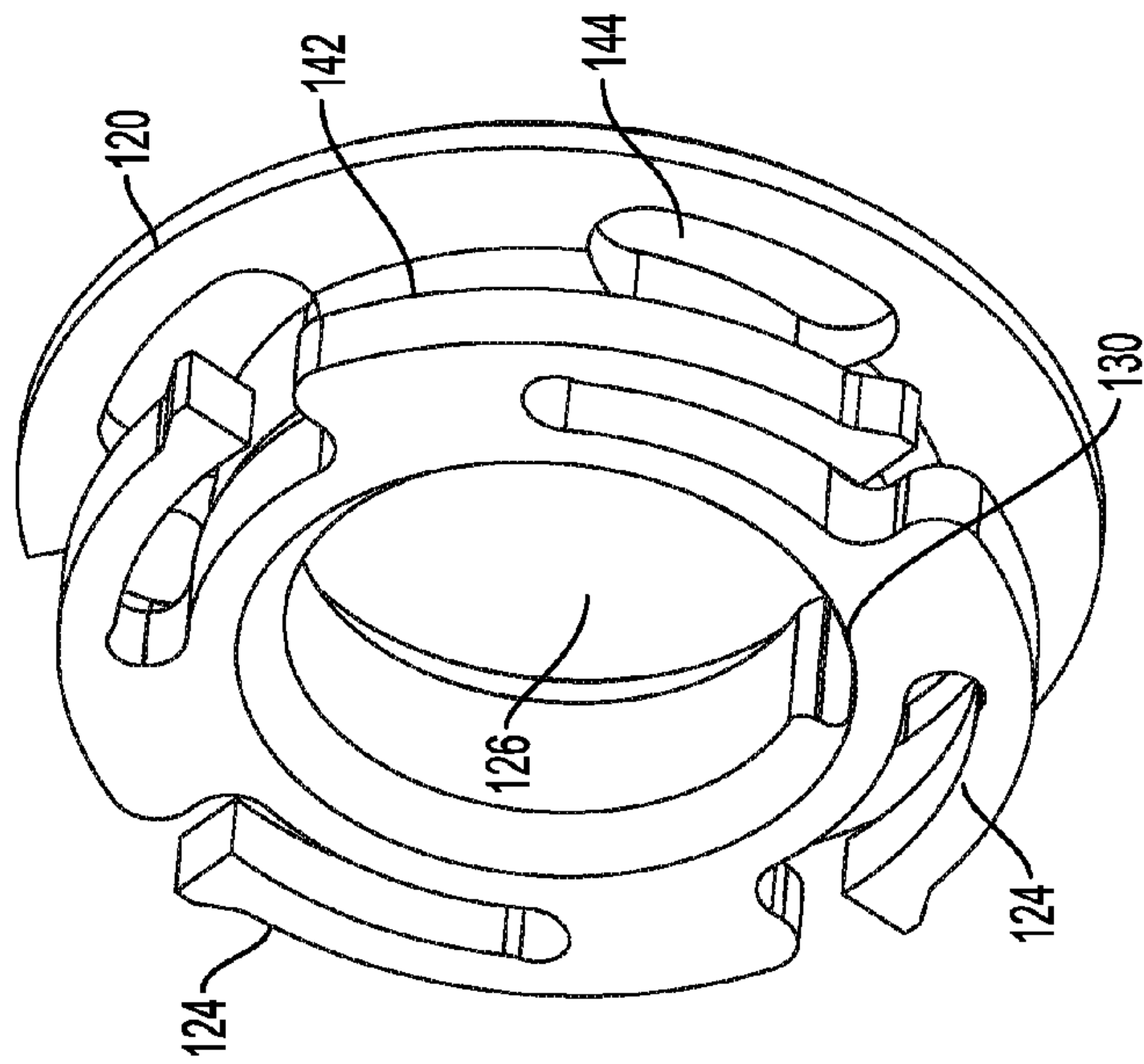


FIG. 3

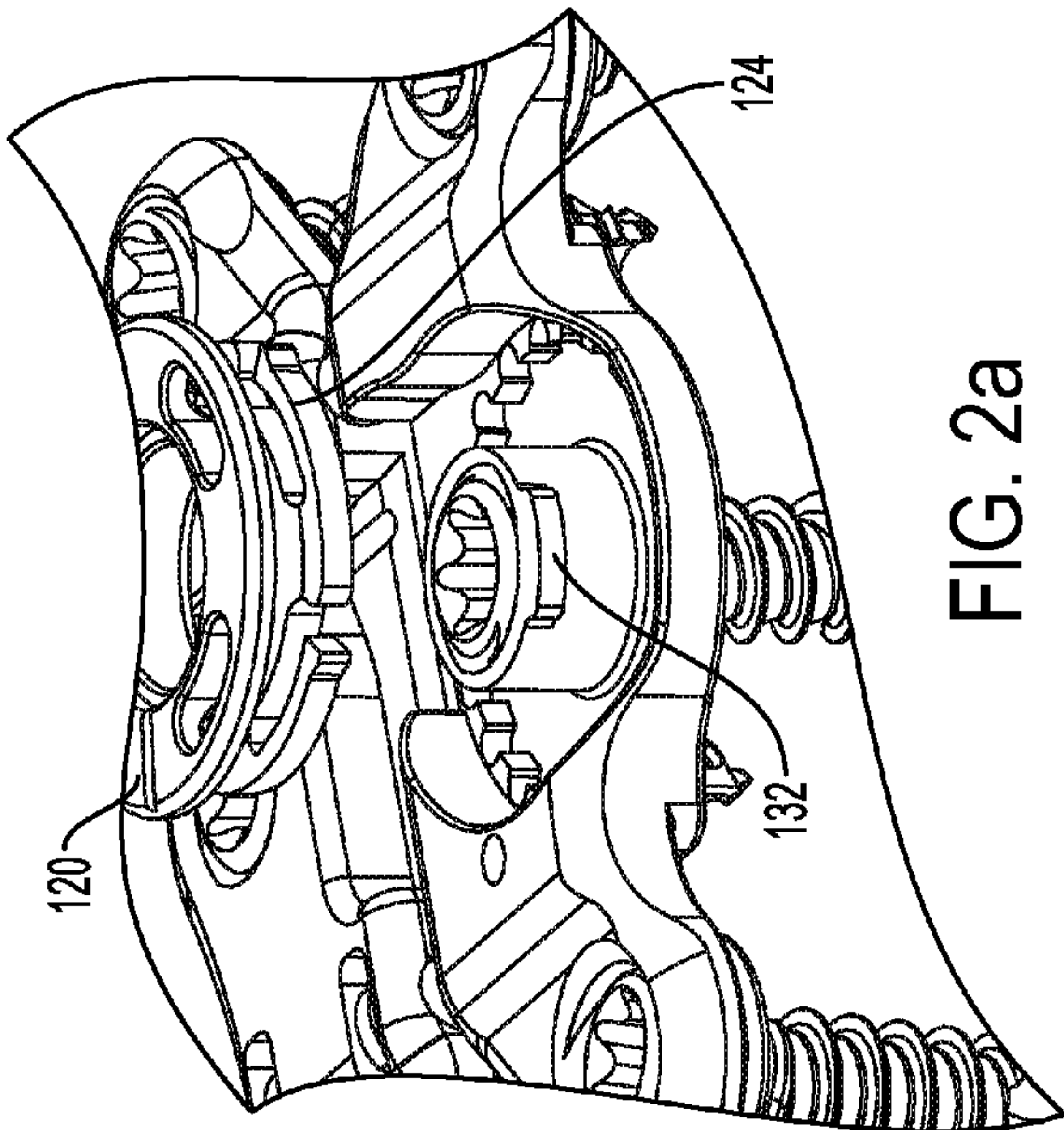


FIG. 2a

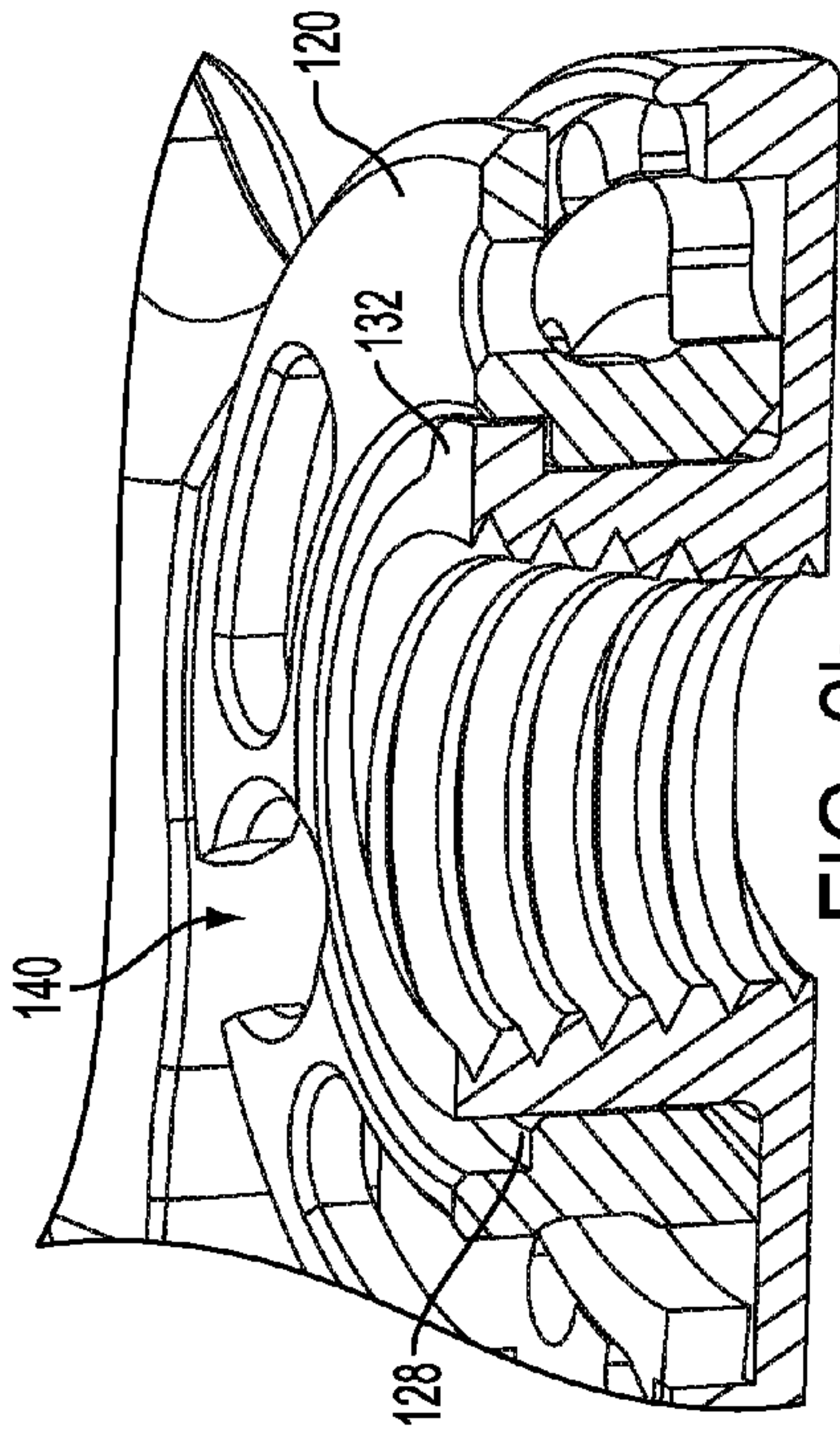


FIG. 2b

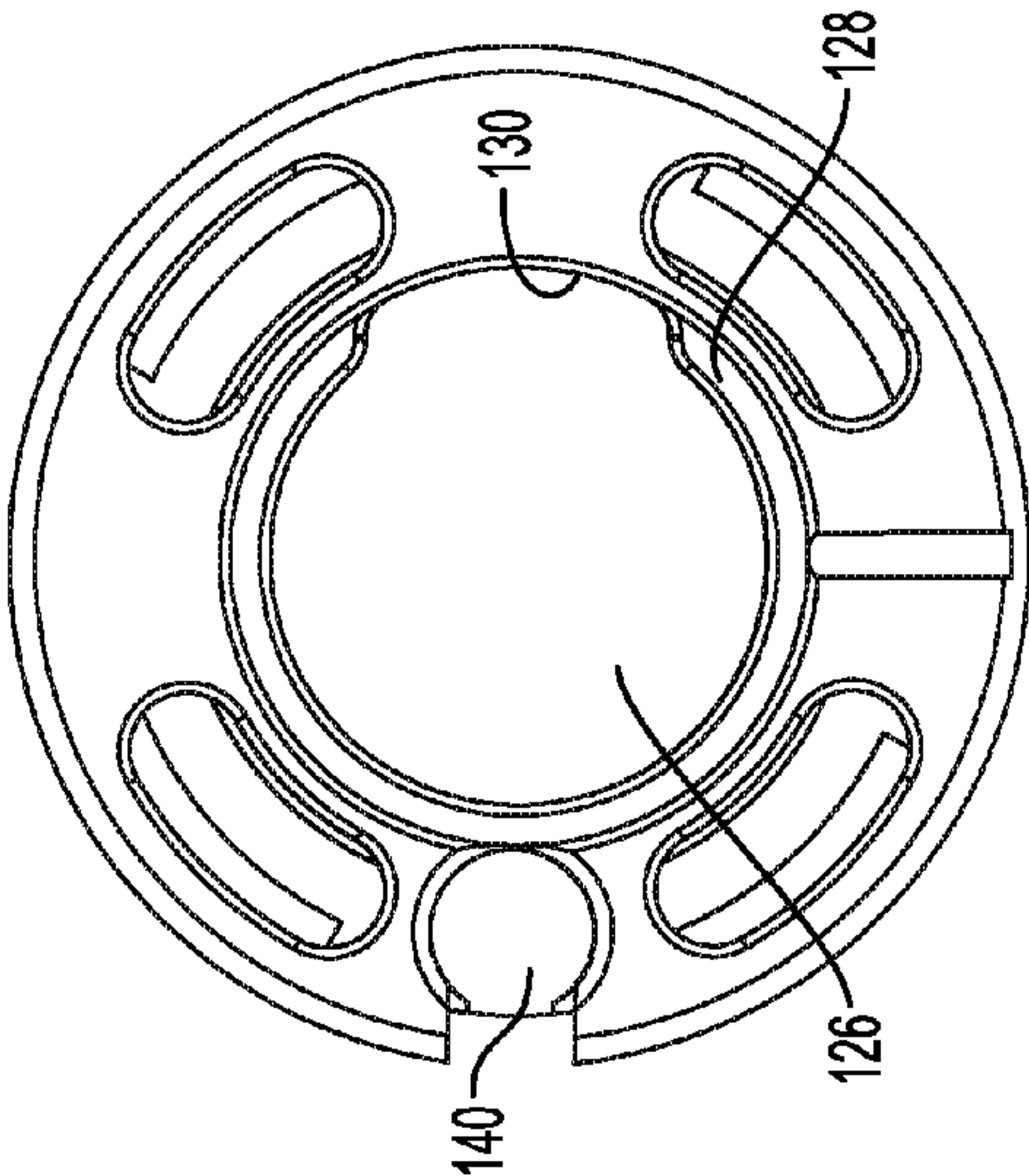


FIG. 2c

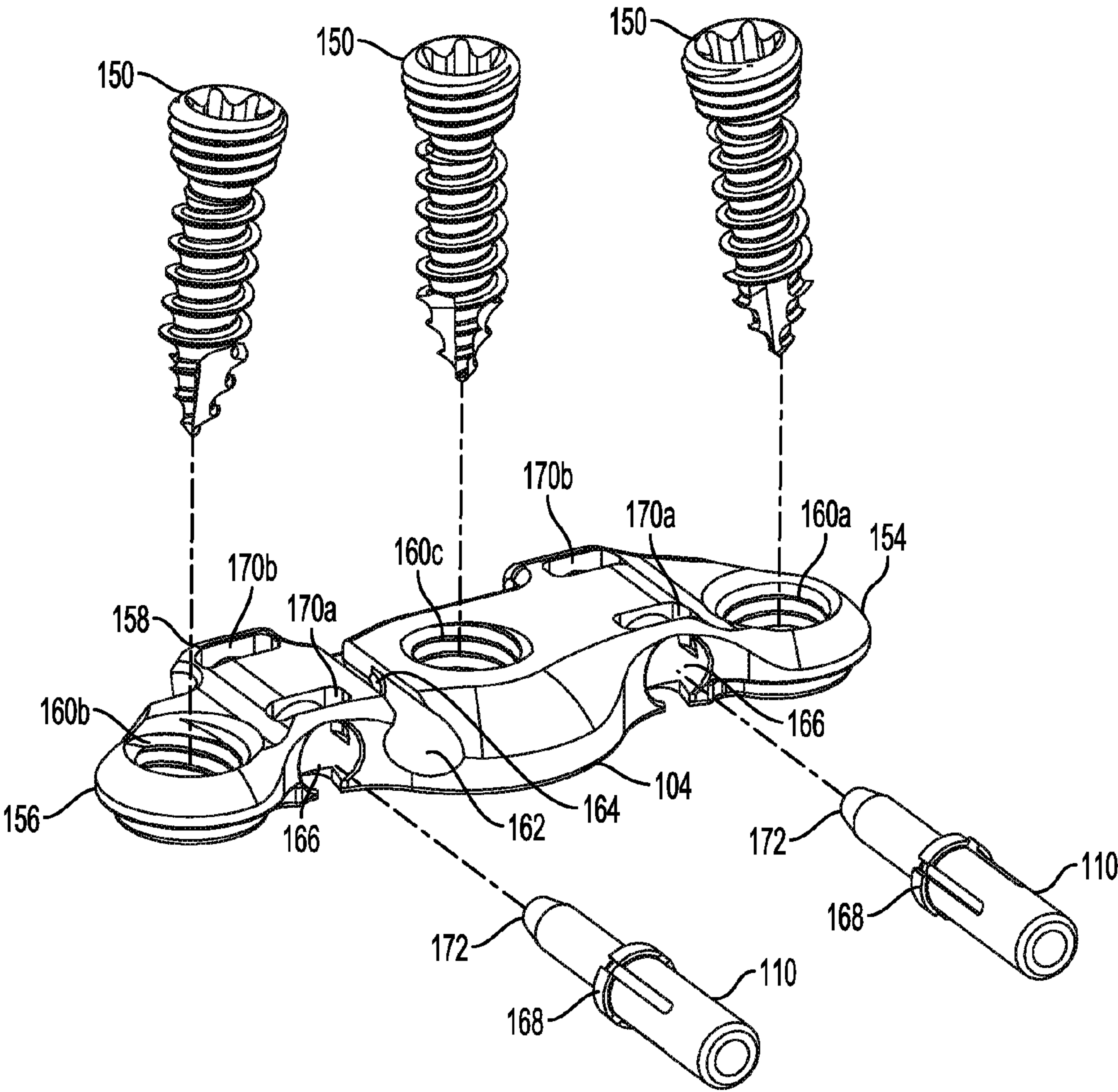


FIG. 4

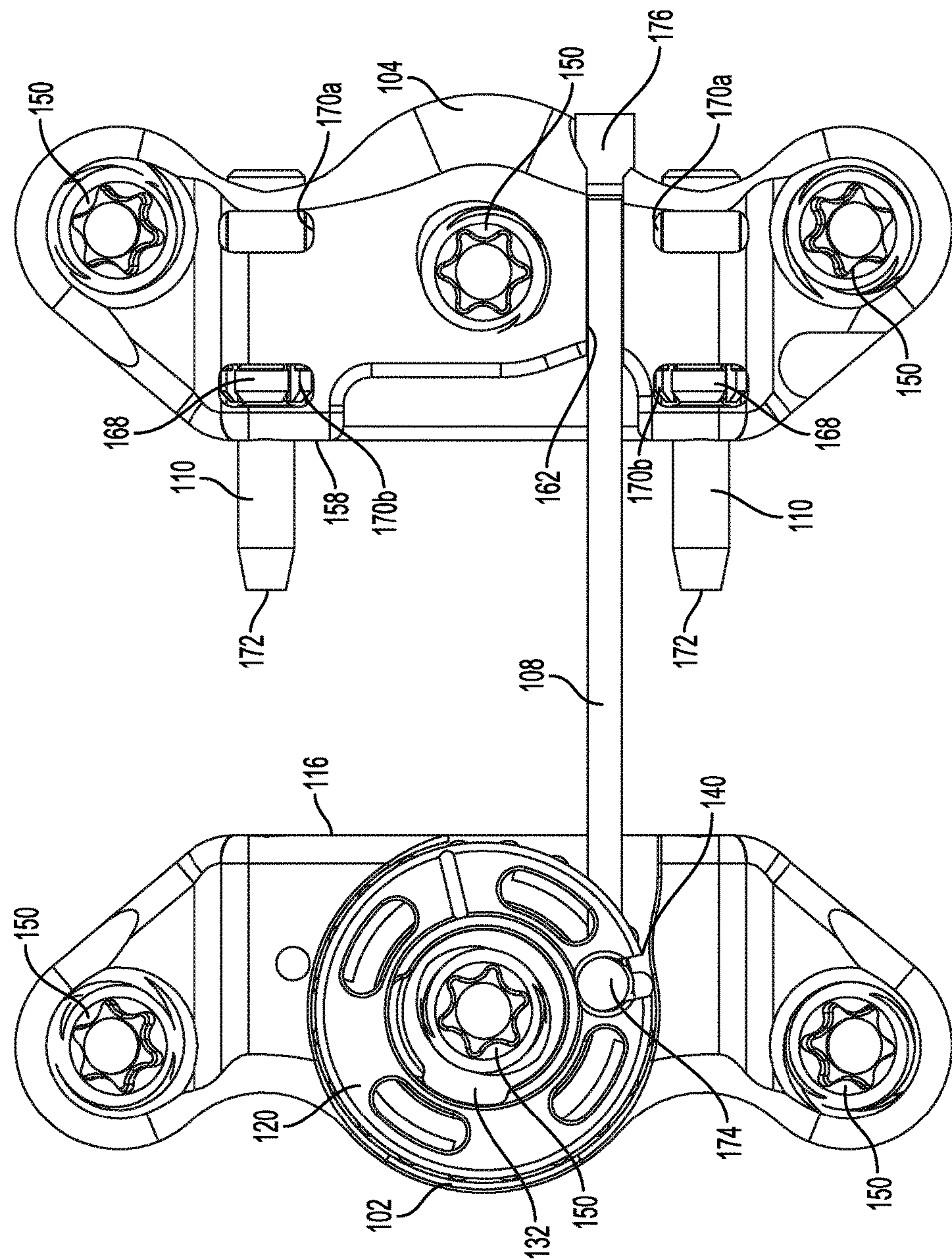


FIG. 5

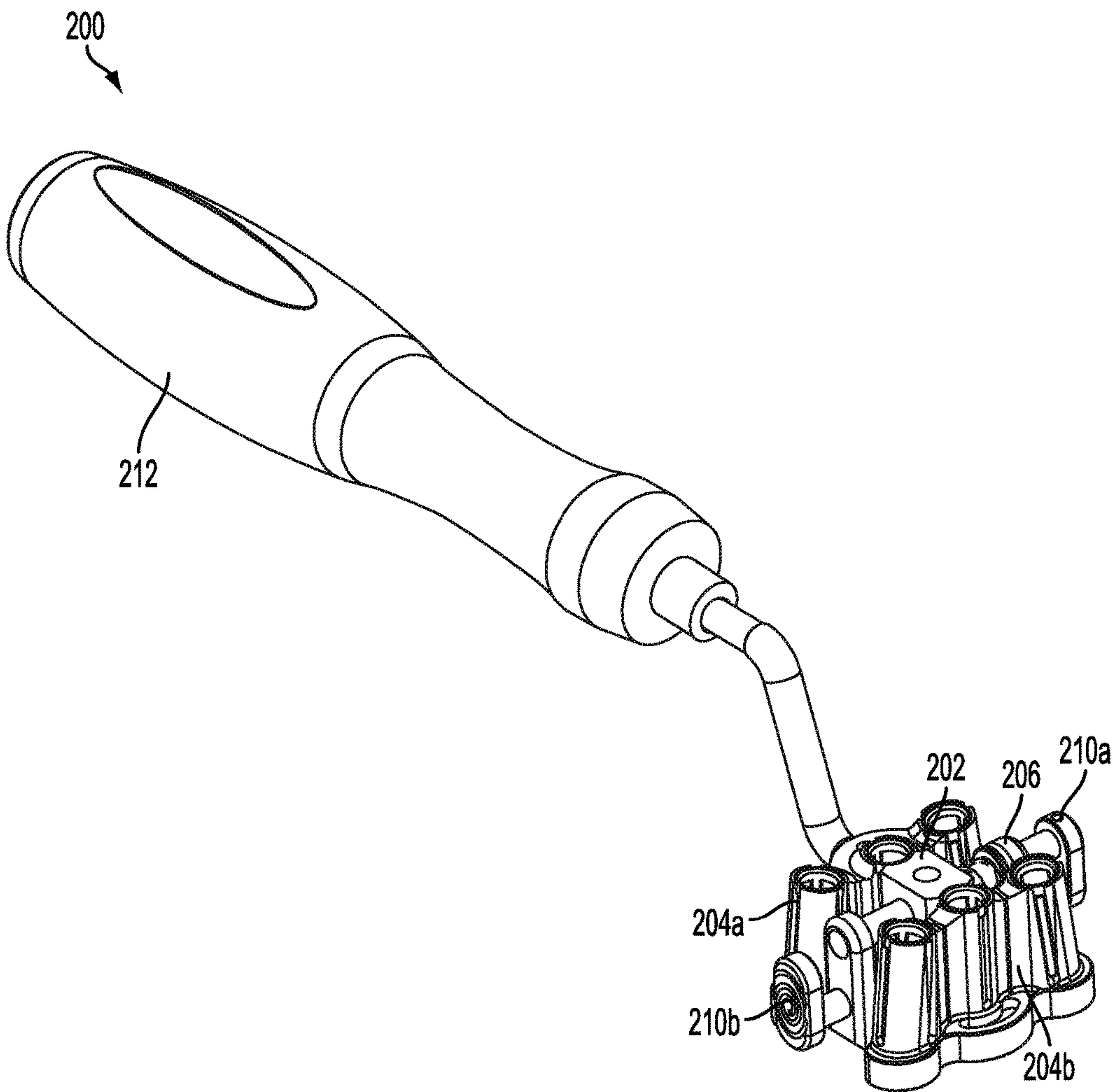


FIG. 6

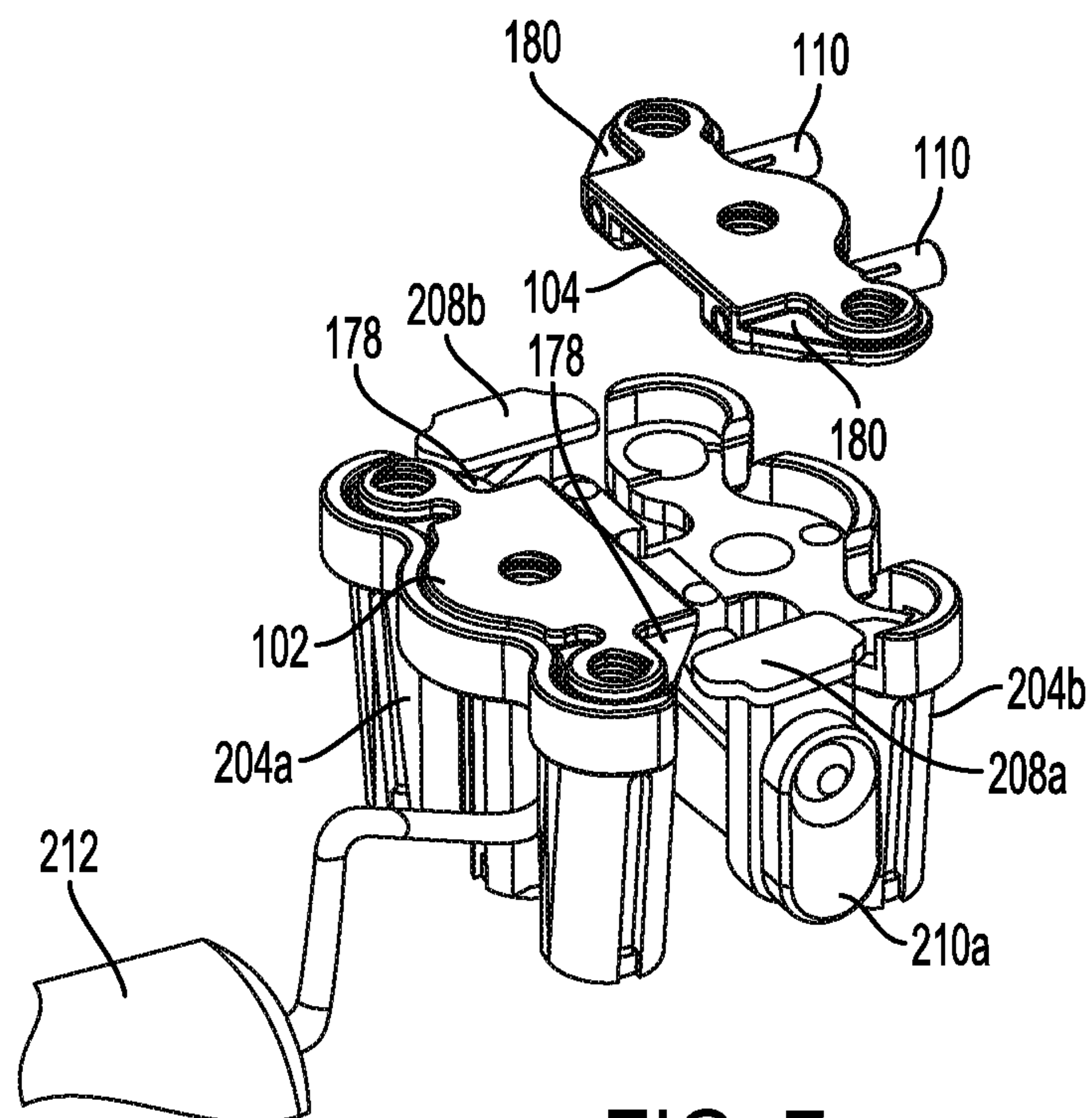


FIG. 7

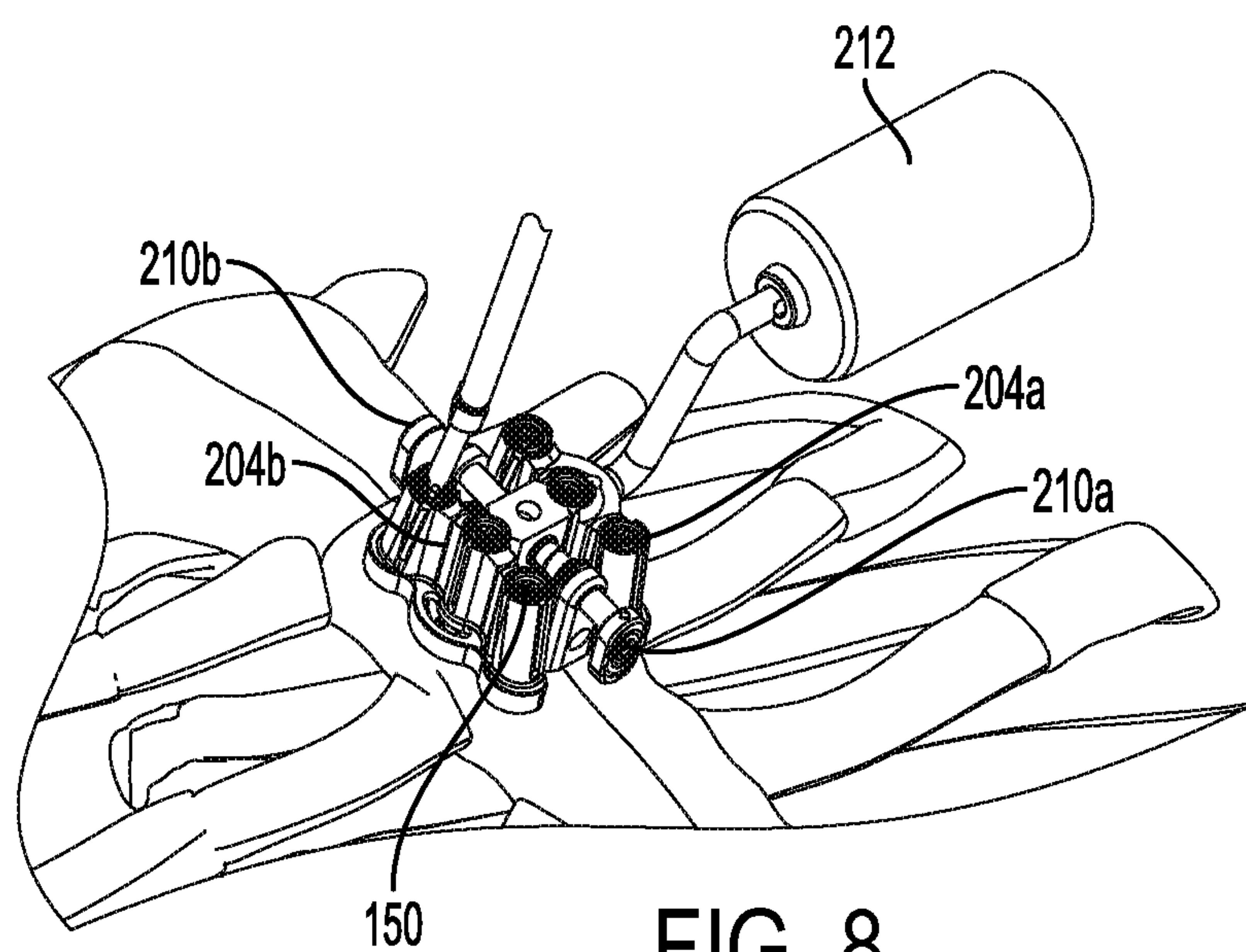


FIG. 8

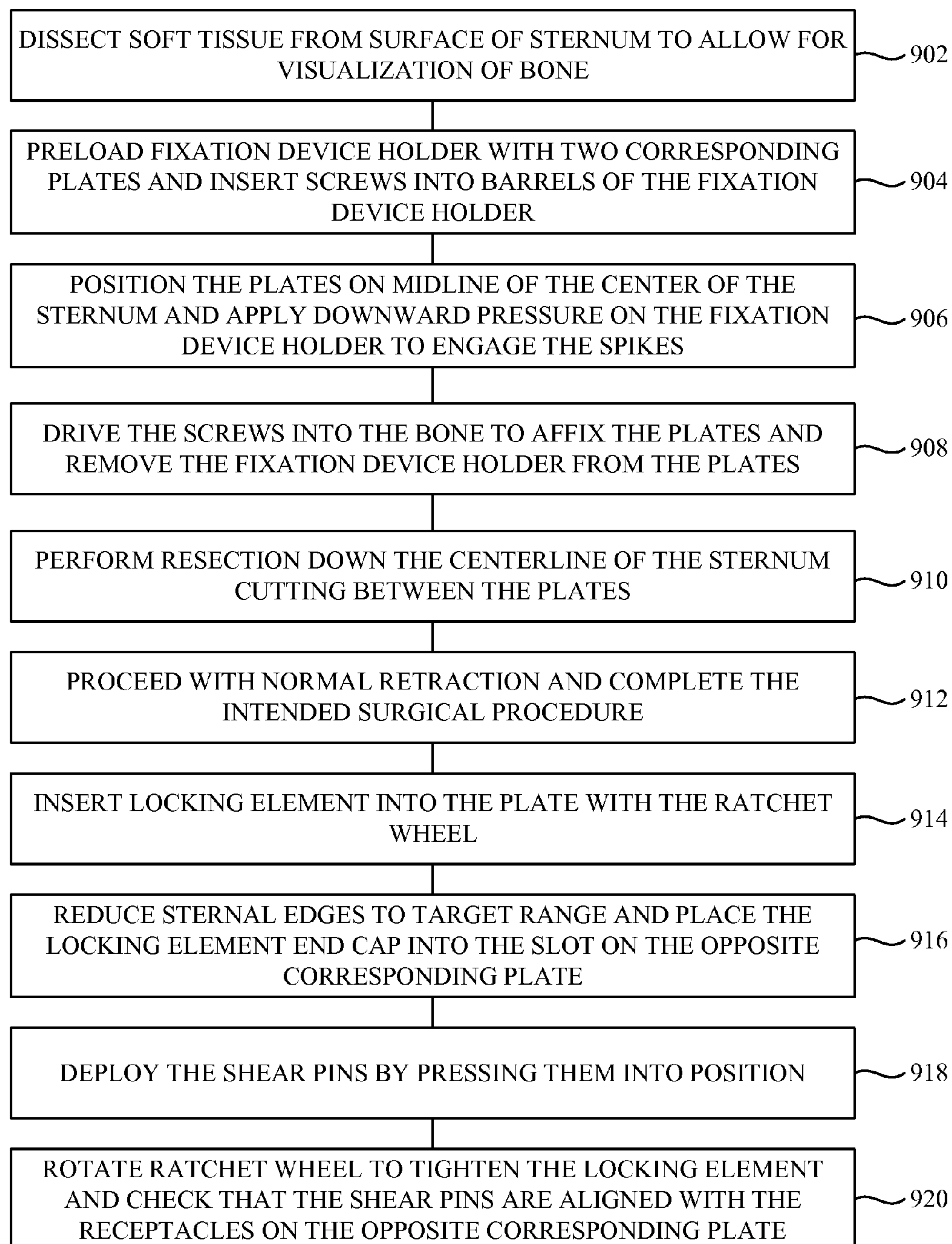


FIG. 9

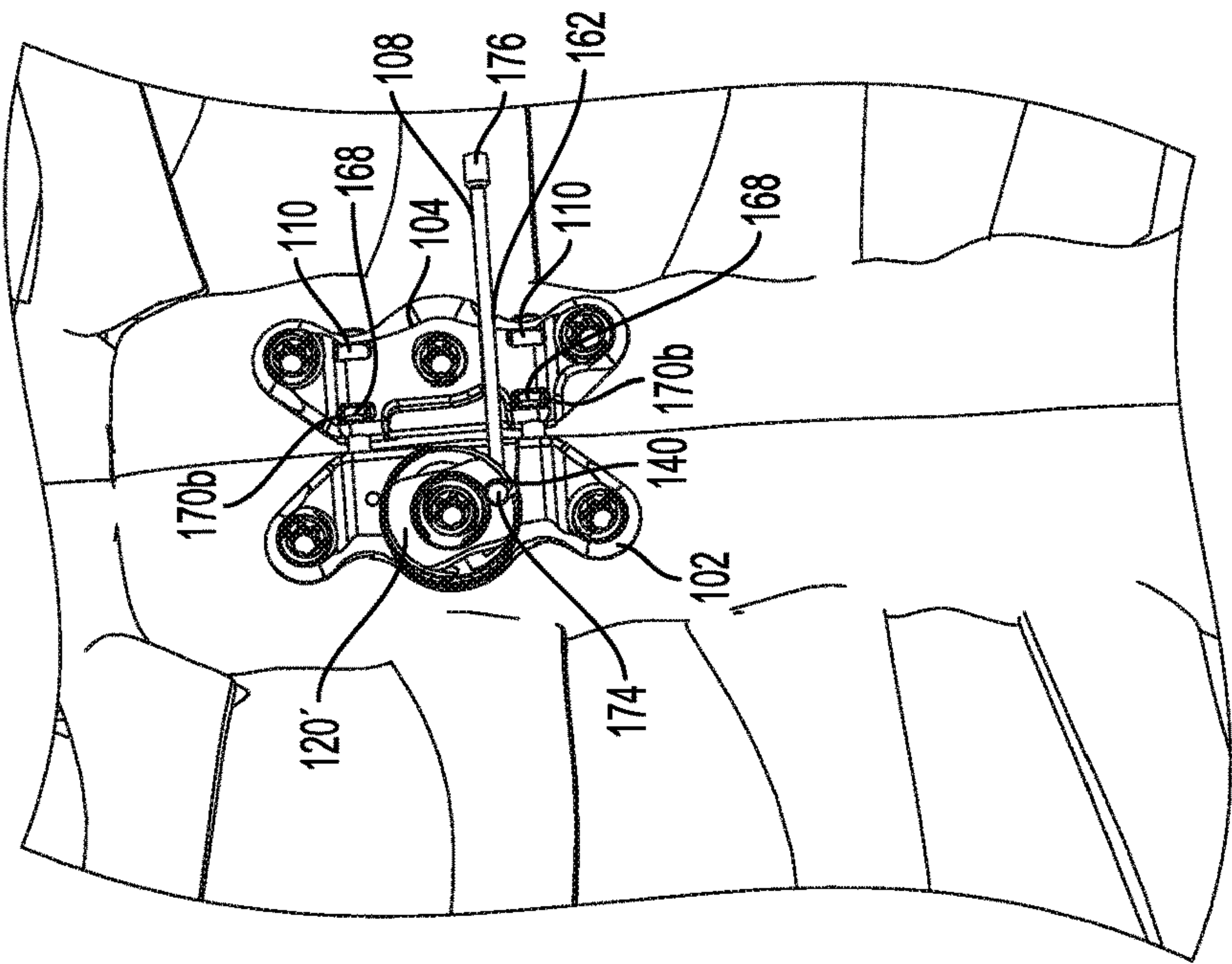


FIG. 10

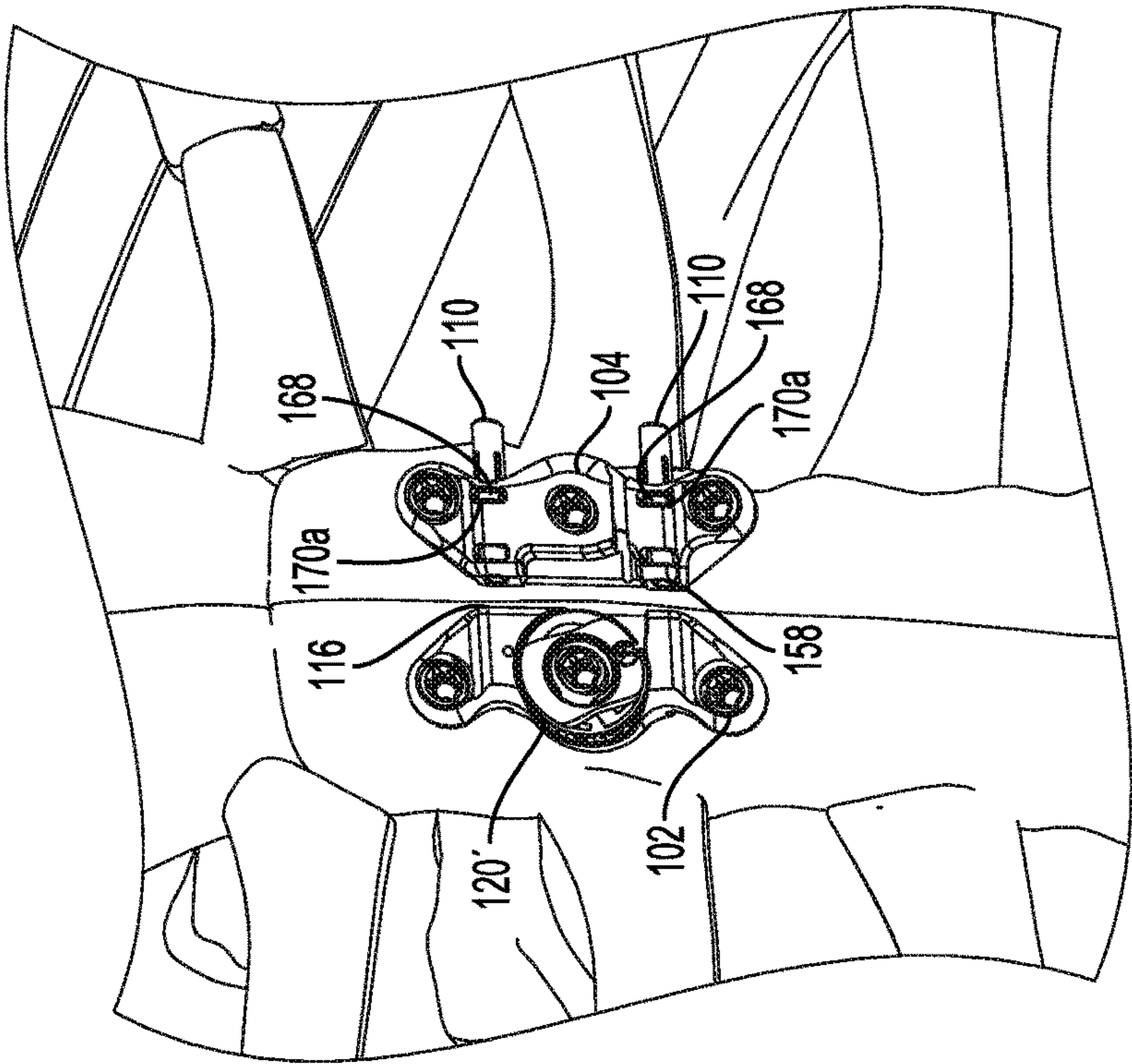


FIG. 11

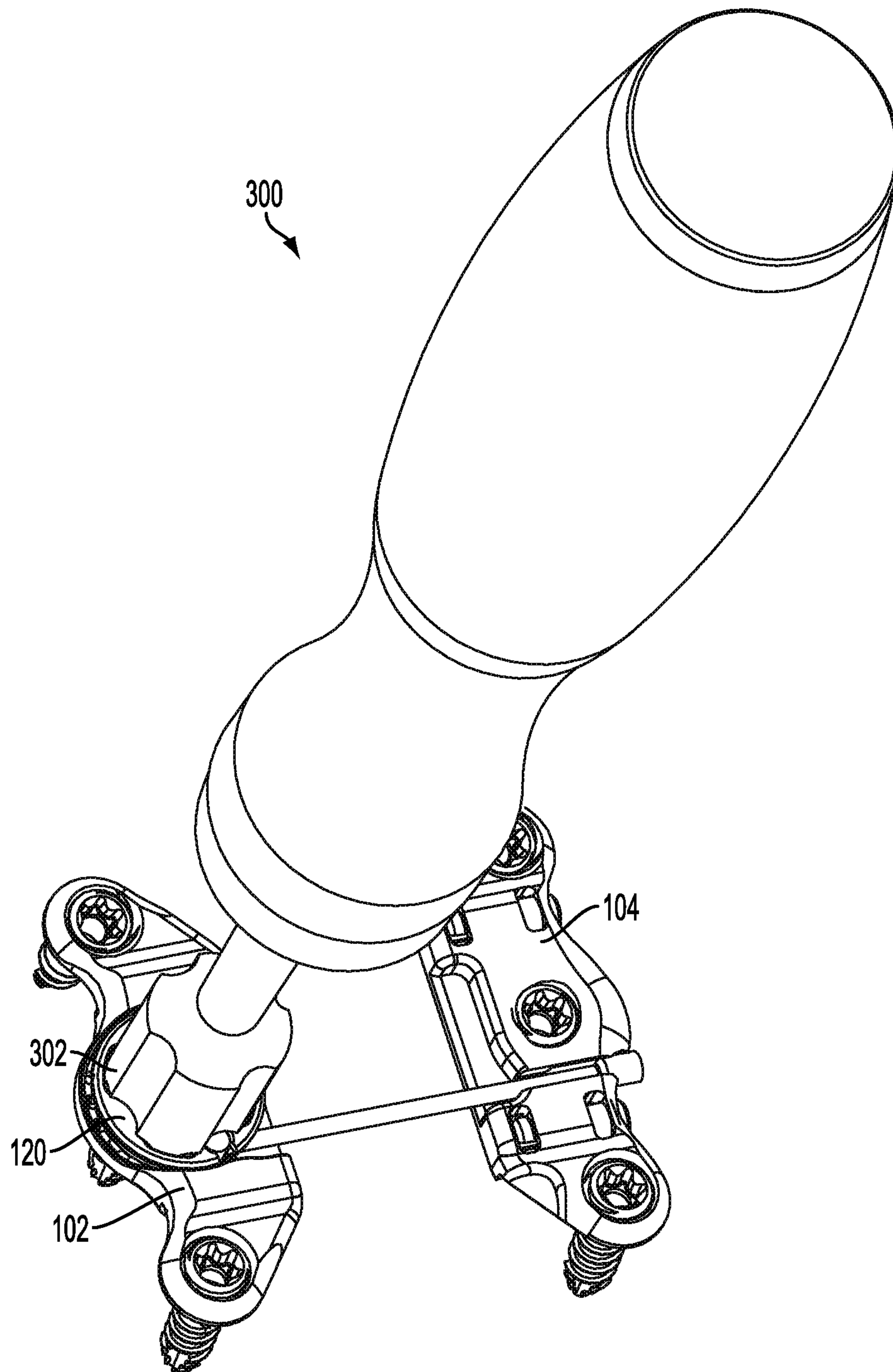


FIG. 12

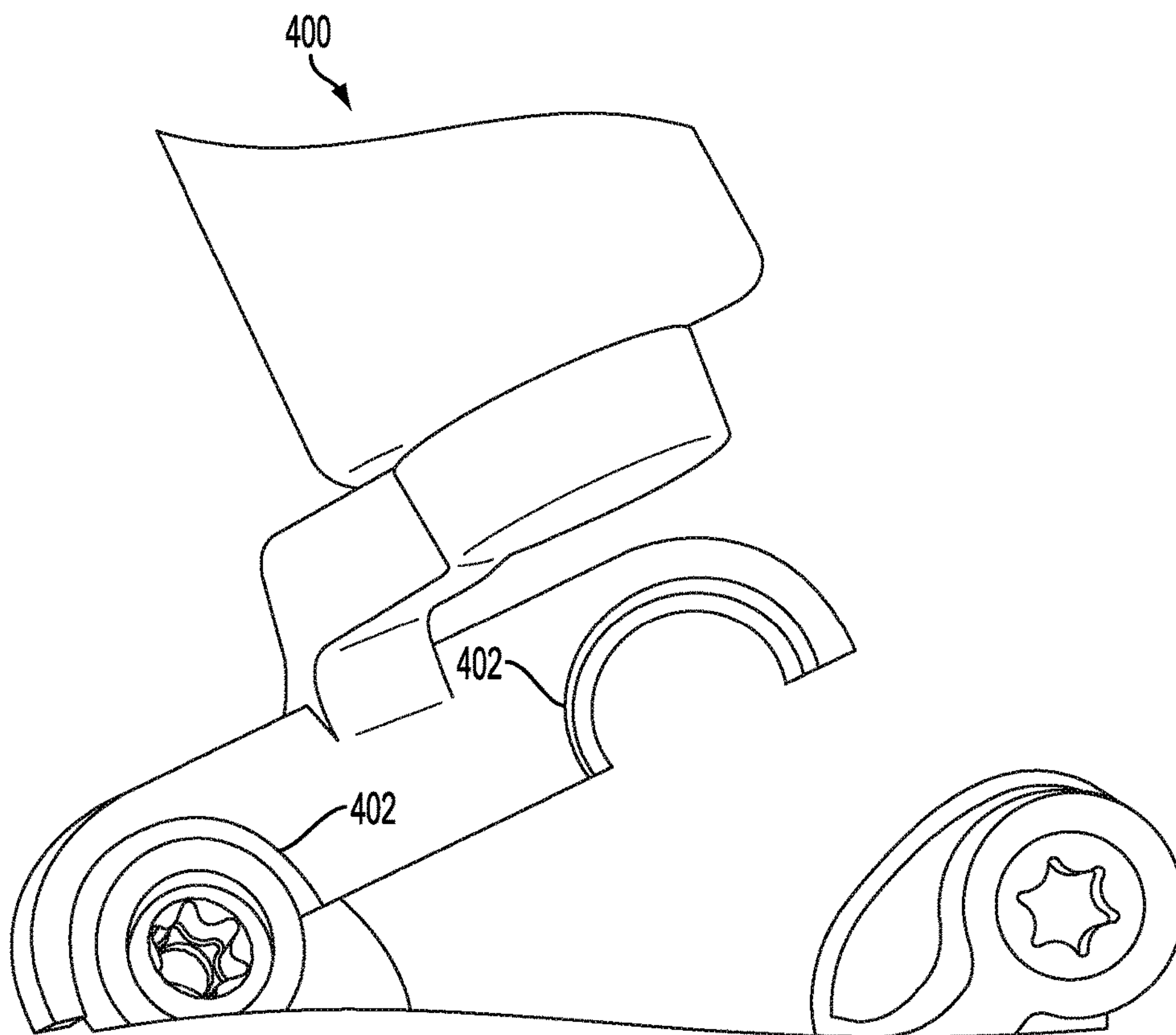


FIG. 13

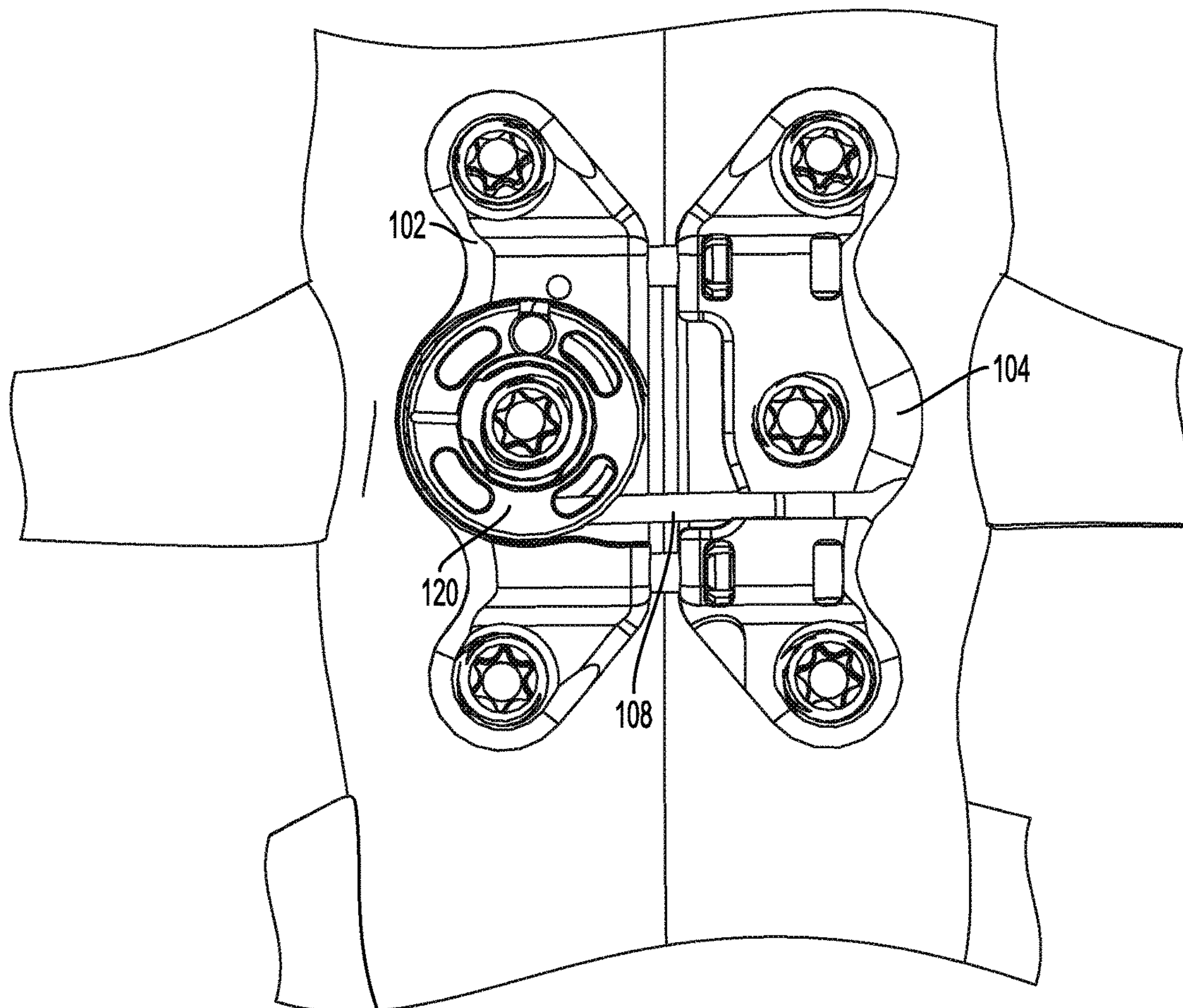


FIG. 14

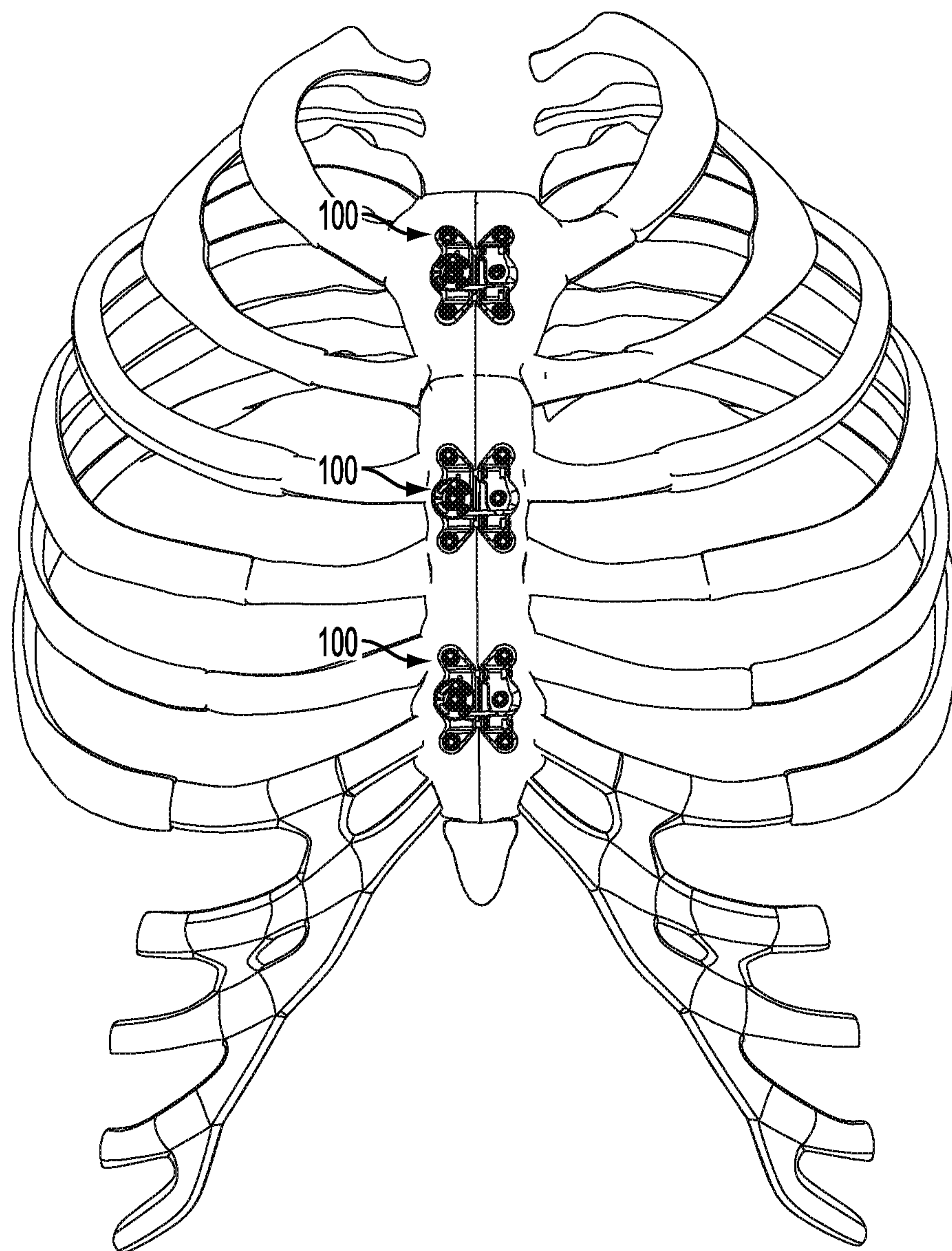


FIG. 15

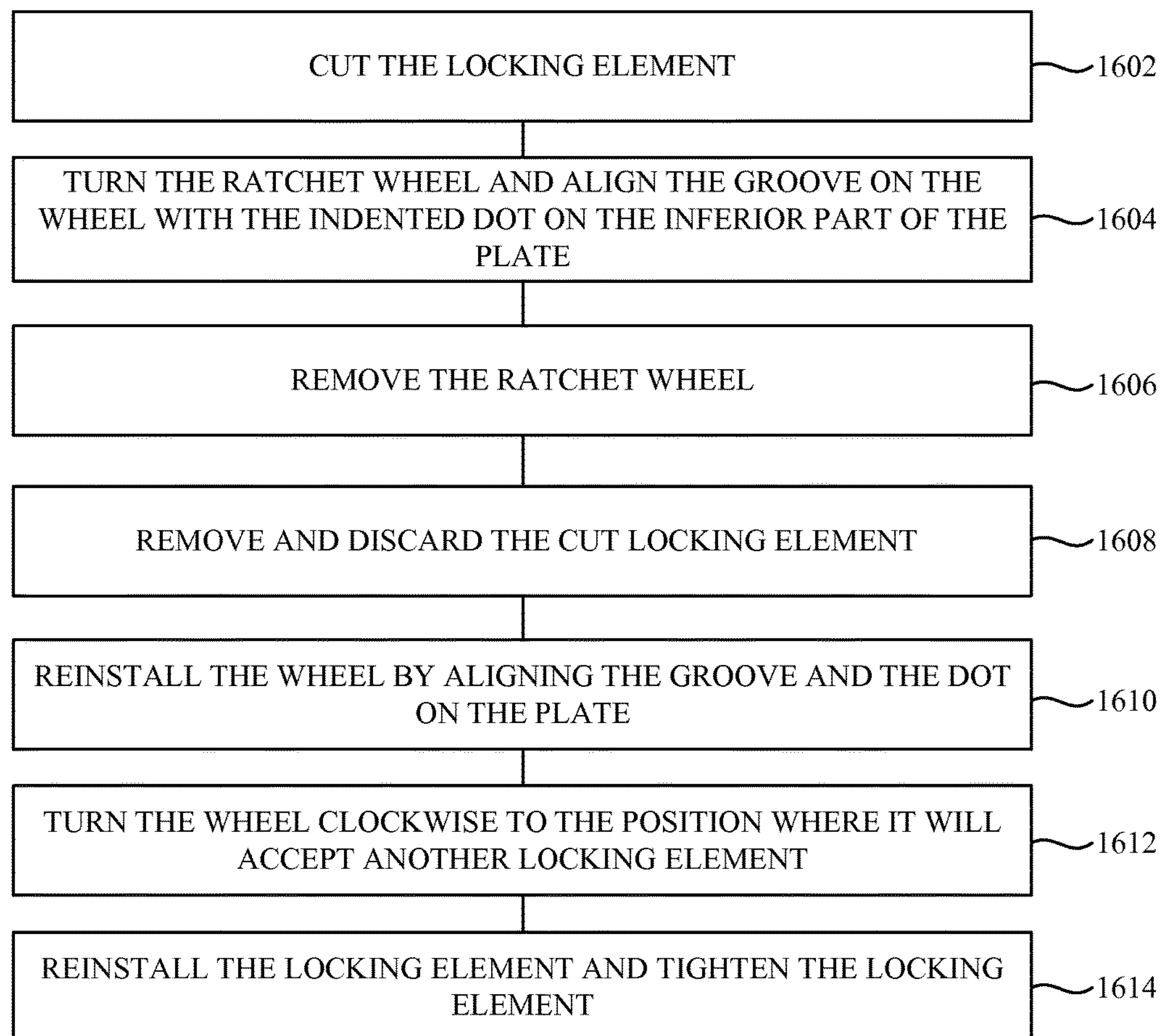


FIG. 16

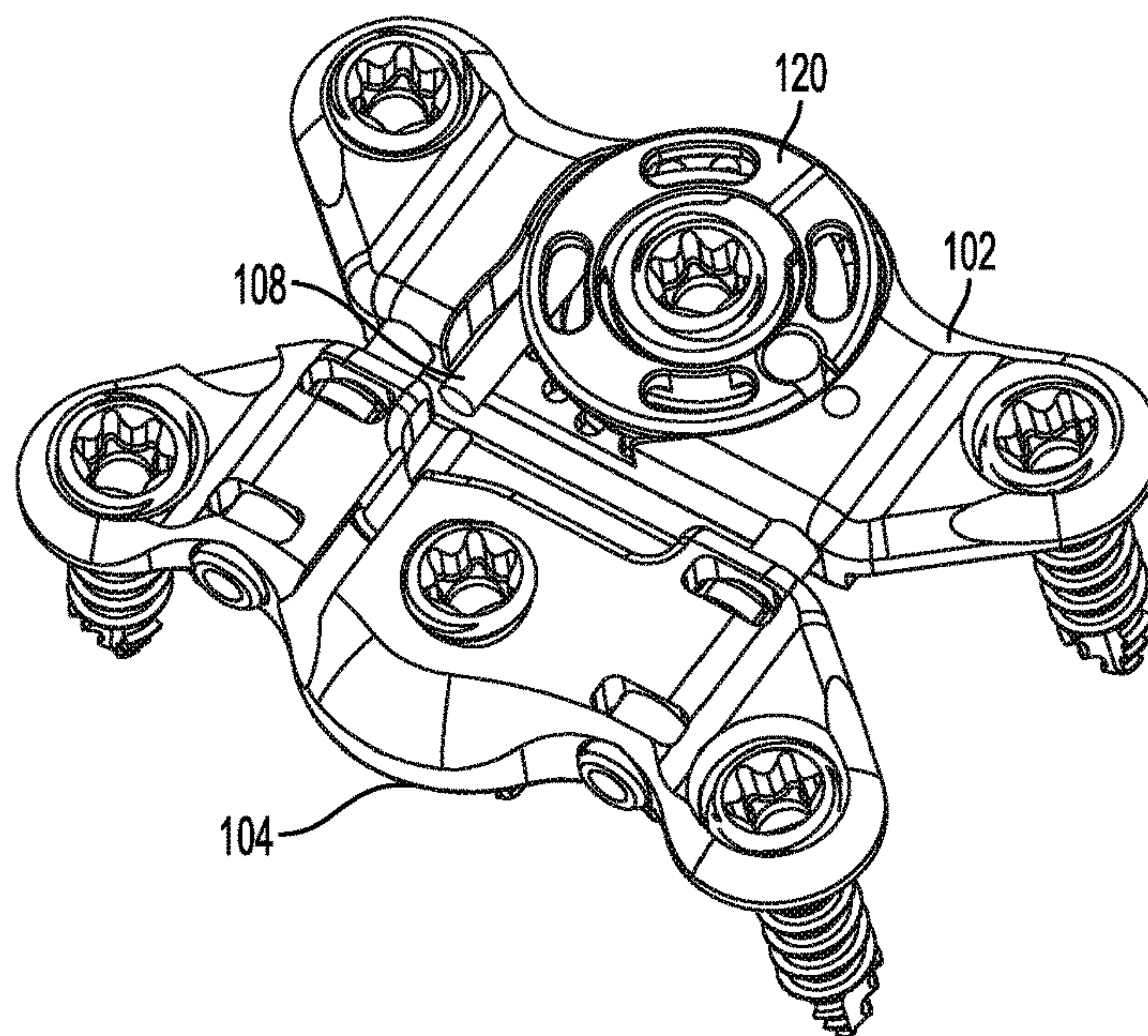


FIG. 17

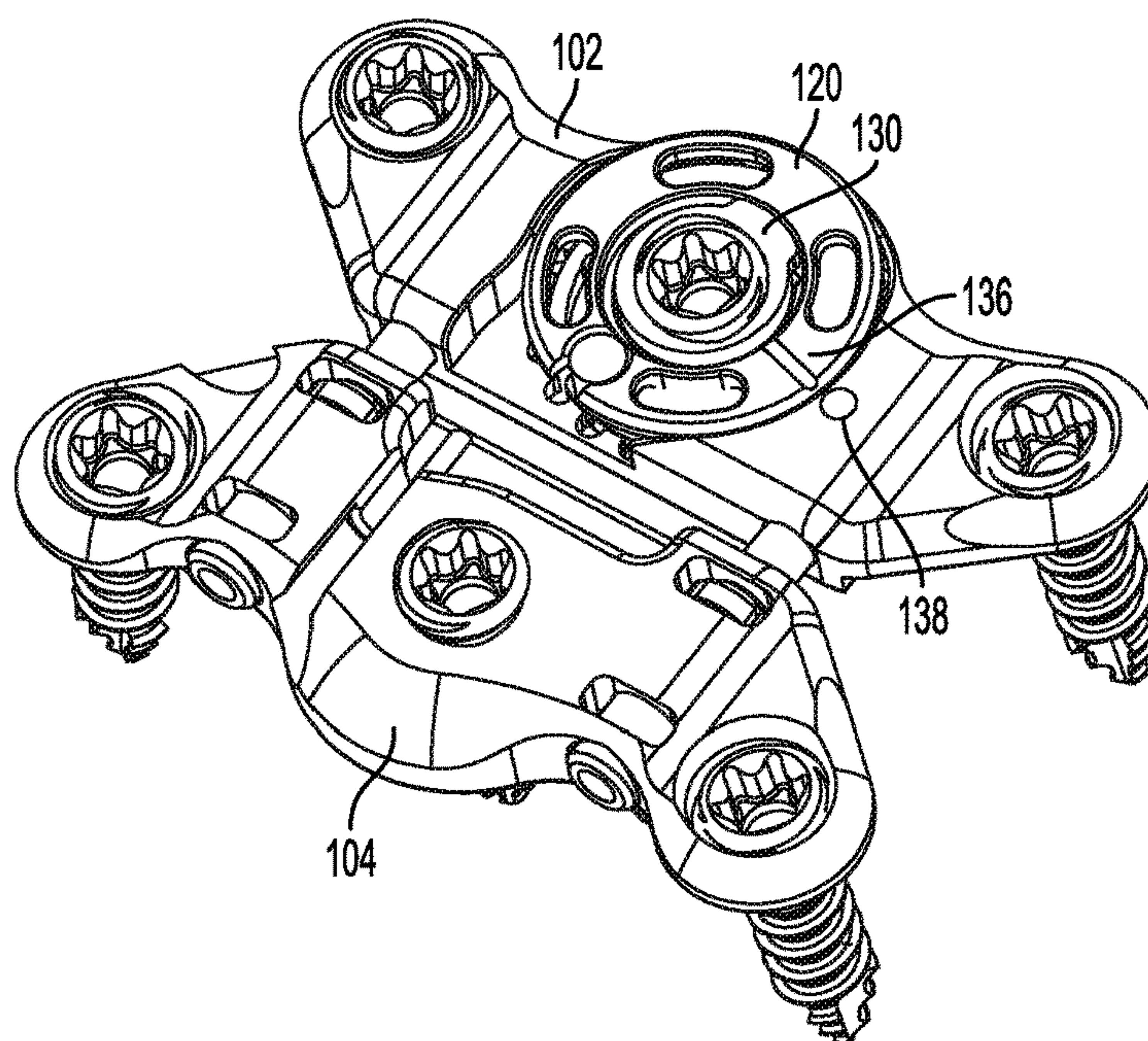


FIG. 18

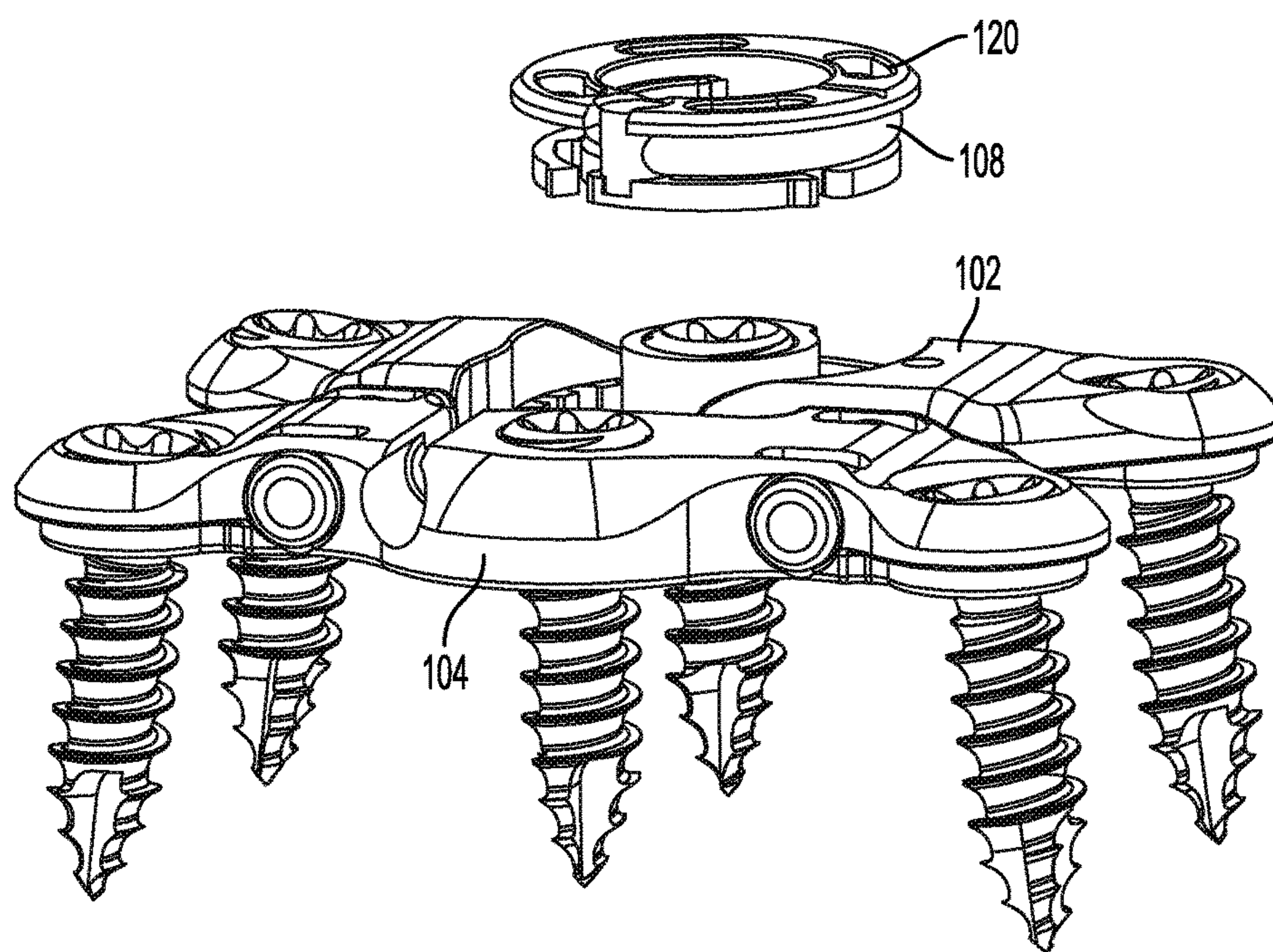


FIG. 19

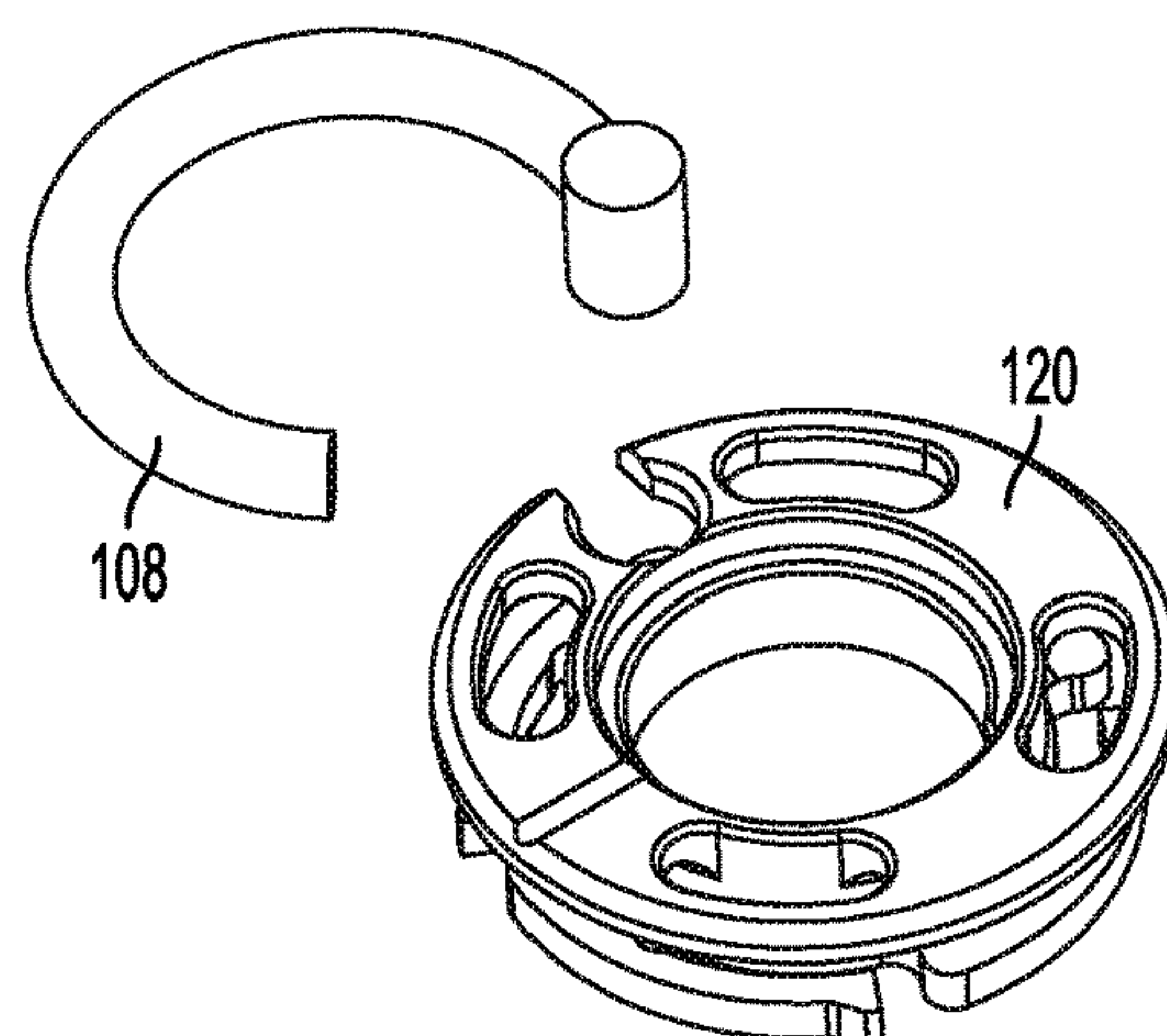


FIG. 20

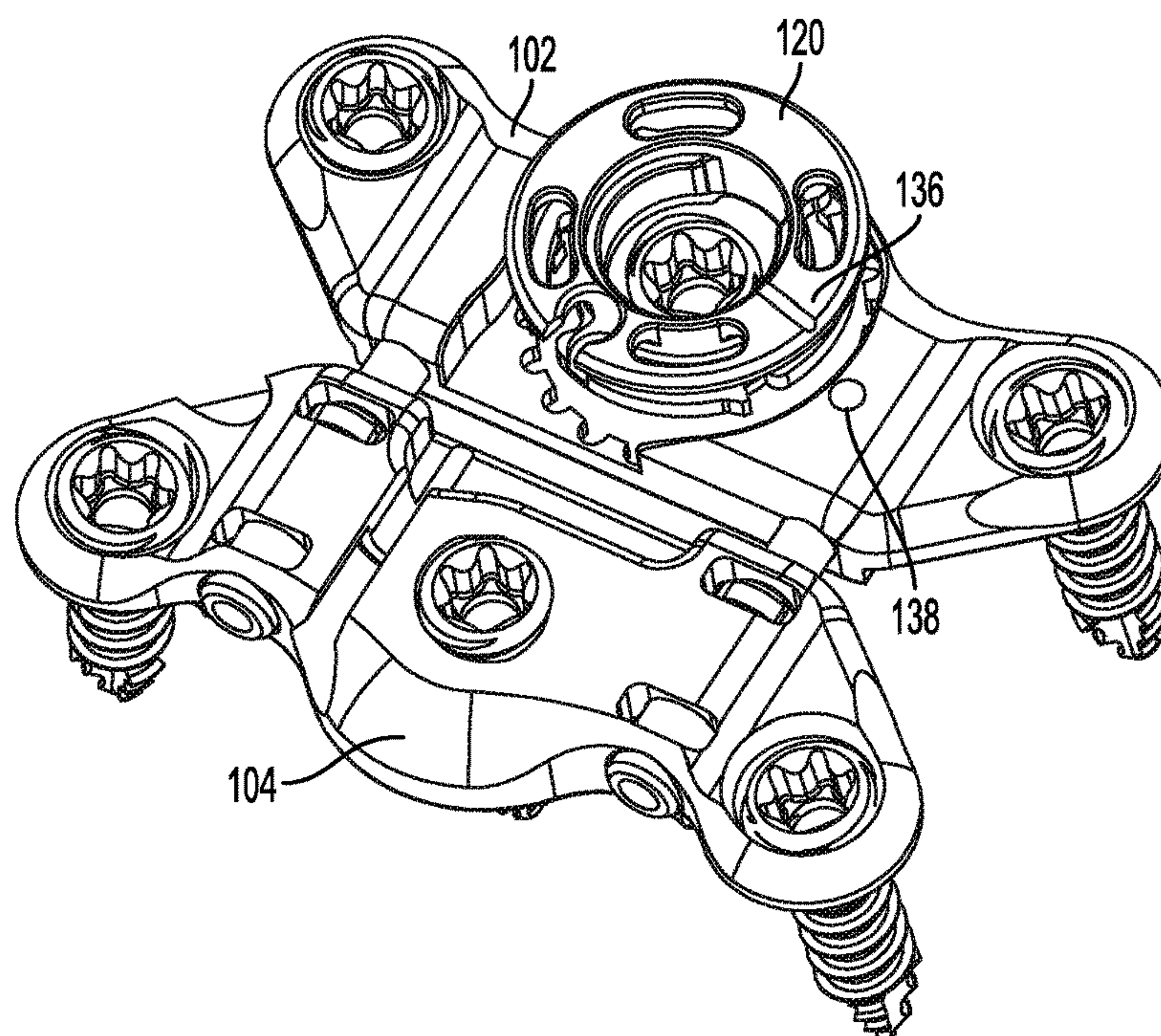


FIG. 21

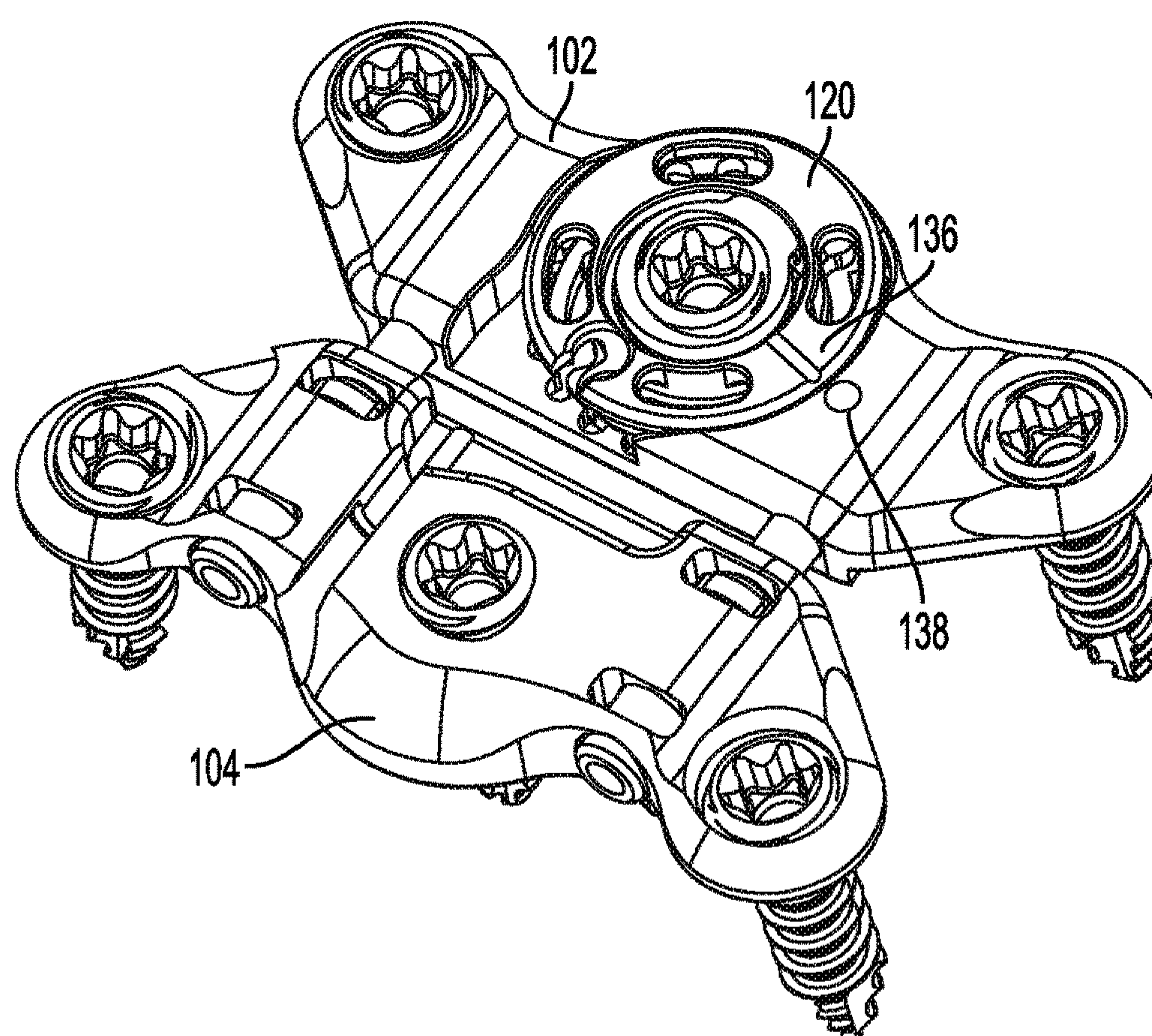


FIG. 22

ORTHOPEDIC FIXATION DEVICE, SYSTEM AND METHOD

CROSS REFERENCES TO RELATED APPLICATIONS

This application claims the benefit of U.S. Provisional Patent Application Ser. No. 61/896,376, filed Oct. 28, 2013, and U.S. Ser. No. 62/039,672, filed Aug. 20, 2014, the content of which is incorporated herein by reference in its entirety.

FIELD

The invention relates generally to orthopaedic fixation devices, systems and methods of such fixation, and particularly regarding use in bone fixation where adjacent sections of a bone, such as a resected bone, are intended to be rejoined.

BACKGROUND

In some surgical procedures involving bones, for instance, the procedure may involve separating a bone into portions, which are thereafter reunited. This happens, for instance, in entries into the chest cavity, as for heart surgery, where the sternum is required to be separated along its length (resected), in the transverse plane, or a combination of the two. There may be other instances where a bone has undergone fracturing through some trauma, and is thereafter to have portions rejoined for proper healing. While discussed herein largely in the context of bones, it will nonetheless be understood that aspects of the invention hereafter described may be applicable to other body parts. Furthermore, the surgical procedure could involve angled or other cuts, and not just a situation where the bone is divided along a length.

The bones or skeletal tissue, or combinations of bone and tissue, can be held secure to one another in adjacency using a fixation device, or system. The system is desirably designed that in the event that subsequent surgery is required, as in an emergency reentry to the chest cavity, the fixation device may be opened quickly and easily with as little harm to the patient as possible. Many kinds of conventional fixation devices of the foregoing type include wires or cables that are organized to pull the bone portions together, laterally across a divide or fracture. These types of fixation devices can be relatively complex to emplace, and require more effort than desired to undue in the event of an emergency. They are also typically emplaced post-resection.

SUMMARY

A device for guiding separation of and rejoining opposed portions of a bone where the portions have been separated, as in a surgical procedure, is disclosed. In an embodiment, the device includes a first plate configured to be disposed on and coupled to the bone and a second plate configured to be disposed on and coupled to the bone and spaced a distance from the first plate. The space allows a cutting tool to be used to create a divide in the bone between the first and second plates. That is, in this form of the invention, the fixation device is emplaced before the bone is separated.

The first plate includes a first face, a ratchet mechanism on a top portion of the first plate facing away from the bone, and a first fastener aperture configured to receive a first fastener to couple the first plate to the bone. The second plate includes a second face configured to oppose and face the first

face when the first and second plates are coupled to the bone, and a second fastener aperture configured to receive a second fastener to couple the second plate to the bone.

The device further includes a locking element that is engageable with the ratchet mechanism and the second plate. The locking element is configured to be coiled in response to operation of the ratchet mechanism to draw the first and second plates together to close the divide.

The ratchet mechanism in one form may include a ratchet recess in the top portion of the first plate and a ratchet wheel disposed in and removable from the ratchet recess. The ratchet recess includes a plurality of teeth around a circumference of the ratchet recess that extend radially inward towards a center of the ratchet recess. The ratchet wheel includes a pawl or pawl-like element configured to engage the ratchet teeth and allow the ratchet wheel to rotate in a first direction while preventing rotation in an opposite direction.

The first plate may further include a boss extending in an upward direction from a central portion of the ratchet recess, and a protrusion proximal to a top edge of the boss extending radially outward from a center of the boss, wherein the first fastener aperture extends through the boss. The ratchet wheel includes a central aperture having a ledge extending substantially circumferentially around the central aperture and extending radially inward toward a center of the central aperture. The central aperture is configured to receive the boss. A cut-out formed in the ledge is configured to allow the protrusion to pass through the central aperture when the cut-out and the protrusion are aligned, and the protrusion extends over the ledge when the ratchet wheel is disposed in the ratchet recess and the cut-out and the protrusion are misaligned.

The device may further include a pin configured to be inserted into a pin aperture extending through the second plate in a substantially perpendicular direction to the longitudinal axis of the second plate. The pin includes a deflectable prong and the second plate includes first and second prong receptacles. The first prong receptacle communicates with the pin aperture and is located distal to the second face. The second prong receptacle communicates with the pin aperture and is located proximal to the second face. The pin is in a first position in which an end of the pin is held within the pin aperture when the deflectable prong is engaged with the first prong receptacle; and a second position in which the end of the pin extends beyond the second face when the deflectable prong is engaged with the second prong receptacle.

The first plate may include a pin receptacle in the first face that is configured to align with the pin aperture and receive the end of the pin when the first and second plate are coupled to the bone and the divide is closed. The pin receptacle has a depth configured to cause the end of the pin to contact a bottom of the pin receptacle when the divide is closed to maintain the first and second plates spaced the distance apart.

It will be understood that the invention can be embodied in other configurations. While described in the context of two interengaging plates, these parts need not be plates per se, but could be in other shapes. Plates have been used in the current environment described hereafter, which is particular, but not limited, to a sternal resection. The sternum presents a rather planar outward facing surface, hence a plate-like structure for the device is particularly useful.

Conceptually, however, the broad concept is in one aspect to have two (or perhaps more) parts for the device that can be emplaced, either before or after the surgical separation (or

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break) across which the device will function to rejoin the separated parts. The device in this form has a ratchet mechanism which serves to draw the parts of the device together, and thus place the bone parts back into rough engagement. The ratchet mechanism could be located on an outward facing surface of the device, or could be formed internally, with a tool access area for turning the ratchet wheel. Preferably, the two (or more) parts of the fixation device also include one or more rigid element, such as rods or flanges for example, which will also span the distance across the divide and serve to further join the parts of the device, particularly against sheer forces (forces that would cause the parts to move relative to one another, either along the divide or into/out of the plane of the fixation device).

Another advantage of the invention in a preferred form is the ability to quickly separate the portions of the device in the event that the bones have to be re-separated post-fixation, as in an emergency procedure. In this form, a simple single cut needs to be made of the joiner element used with the ratchet mechanism, then the parts are movable laterally. To thereafter re-join the still emplaced parts, a new joiner element is used. The ratchet mechanism could be made replaceable to that end (pop-out pop-in), or conceivably could be designed simply to receive a new joiner element.

BRIEF DESCRIPTION OF THE DRAWINGS

Embodiments of devices, systems, and methods are illustrated in the figures of the accompanying drawings which are meant to be exemplary and not limiting, in which like references are intended to refer to like or corresponding parts, and in which:

FIG. 1 illustrates a perspective view of an implantable fixation device according to an aspect of the disclosure;

FIG. 2 illustrates an exploded view of a first plate of the implantable fixation device of FIG. 1 according to the disclosure;

FIGS. 2a through 2c illustrate the ratchet wheel attachment of the device of FIG. 1;

FIG. 3 illustrates a perspective view of a ratchet wheel of the first plate of FIG. 1 according to the disclosure;

FIG. 4 illustrates an exploded view of a second plate of the implantable fixation device of FIG. 1 according to the disclosure;

FIG. 5 illustrates the first and second plates aligned in a first position;

FIG. 6 illustrates a fixation device positioning holder according to the disclosure;

FIG. 7 illustrates the first and second plates being installed in the fixation device positioning holder according to the disclosure;

FIG. 8 illustrates the first and second plates being affixed to a bone according to the disclosure;

FIG. 9 is a block flow diagram of a method of installing and using the implantable fixation device according to the disclosure;

FIG. 10 illustrates the first and second plates of FIG. 1 aligned and oriented in a pre-resection position according to the disclosure;

FIG. 11 illustrates the first and second plates of FIG. 1 aligned and oriented in a first post-resection position prior to operation of a ratchet mechanism according to the disclosure;

FIG. 12 illustrates a tool for operating a ratchet wheel of the first plate according to the disclosure;

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FIG. 13 illustrates a reduction tool for aligning and holding the first and second plates post-resection according to the disclosure;

FIG. 14 illustrates the first and second plates of FIG. 1 post-resection according to the disclosure;

FIG. 15 illustrates a plurality of first and second plates post-resection as they might be located according to the disclosure;

FIG. 16 is a block flow diagram of a method of using the implantable fixation device for reentry/re-resection of the bone according to the disclosure;

FIGS. 17 through 20 illustrate a locking element being cut and removed according to the disclosure; and

FIGS. 21 and 22 illustrate the ratchet wheel being reinstalled after removal of the locking element.

DETAILED DESCRIPTION

While the embodiments described hereinafter are in the environment of an orthopaedic fixation device, system and method for use on the sternum, in particular, it should be appreciated that the disclosure has broader application. That could be, for instance, such as where bone or other body parts having suitable rigidity require closure or other relational organization, such as joining two opposing anatomical structures. This could be in the context of a traumatic break or other unintended separation, or as part of a surgical procedure. Thus, the present disclosure can have usefulness in contexts beyond fixation of bones which have been resected in surgery.

In general, the present disclosure relates to implantable fixation devices for rejoining opposed portions of a separated bone. Implantable is used in the sense that it is sub-cutaneous, but it is possible that applications leaving the fixation device external could be envisioned.

One such device which has been developed according to aspects of the invention in the context of joining two halves of the sternum, includes two corresponding plates that are configured to be aligned and coupled to a bone, such as a sternum, pre-resection of the bone or prior to cutting/separating the bone. The placement of the corresponding plates provides a gap between the edges of the plates that face one another allowing for and guiding a cutting tool for separating the bone. After the bone has been cut and the desired surgical procedure performed, the plates also assist in realigning and fixation of the bone portions. For example, at least one plate may include a ratchet mechanism that is configured to tighten a locking element and draw the two plates together and into alignment with one another.

Note here again, the fixation device could also be emplaced post-resection, although this is considered a less-advantageous use of the device as currently perceived. Also, the parts of the device need not be plates or planar elements, but this shape was considered most-desirable in the environment of a sternal rejoining device and system.

FIGS. 1-5 illustrate an implantable fixation device 100 in the form of two plates according to an embodiment of the disclosure. As illustrated in FIG. 1, the fixation device 100 includes a first plate 102 and a second plate 104. The first plate 102 includes a ratchet mechanism 106 for use in tightening a locking element 108 to pull the first plate 102 and second plate 104 together, as will be more particularly described hereafter. One or more shear pins 110 may be inserted into the second plate 104 to assist in aligning the first plate 102 and second plate 104, and to resist longitudinal and transverse shear forces applied to bone portions post-separation. Other interengaging elements spanning the

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divide and serving to stabilize the adjacent plates against these forces can be envisioned.

Referring to FIG. 2, the first plate 102 includes a first end 112, a second end 114, and a first face 116 configured to be positioned facing a face of the second plate 104, and the ratchet mechanism 106. The ratchet mechanism 106 includes a ratchet recess or well 118 and a ratchet wheel 120. The ratchet recess 118 is located in substantially a central portion of a top portion (i.e., facing away from a body/bone onto which the plate may be attached) of the first plate 102 between the first and second ends 112 and 114. As illustrated, the ratchet recess 118 includes a plurality of teeth 122 around a circumference of the ratchet recess 118 that extend radially inward towards a center of the ratchet recess 118. Other types of ratcheting mechanisms can be envisioned. For instance, rather than a wheel, a post or boss could be used upon which the locking element may be received.

The ratchet wheel 120 is removably disposed in the ratchet recess 118. This will be more particularly described with relation to re-entry after an earlier fixation procedure, as for emergency reentry. Referring to FIGS. 2 and 3, the ratchet wheel 120 includes one or more pawls 124 configured to engage the teeth 122 and allow the ratchet wheel to rotate in one direction while preventing rotation in the opposite direction. As illustrated, the ratchet wheel 120 includes four pawls 124 and the ratchet recess 118 includes 20 teeth 122. This provides for a ratchet mechanism that locks, thereby preventing rotation in the opposite direction, at about each eighteen degree increment of rotation. However, it should be appreciated that the number of pawls 124 and teeth 122 may be increased or decreased to provide a ratchet mechanism that locks, thereby preventing rotation in the opposite direction, at any desired degree increment of rotation.

The ratchet wheel 120 also includes an aperture 126 including a ledge 128 extending substantially circumferentially around the aperture 126 and extending radially inward toward a center of the aperture 126. Perhaps best illustrated by reference to FIGS. 2a through 2c, the ratchet wheel attachment utilizes a cut-out or groove area 130 configured to receive a protrusion 132 of a boss 134. The boss 134 extends in an upward direction from a central portion of the ratchet recess 118 and includes the protrusion 132 proximal to a top edge of the boss 134 that extends radially outward from a center of the boss 134. This protrusion and groove 130 arrangement allows for the wheel to be put into place and then held in the well. Once the wheel is advanced, then the protrusion is captured, holding the ratchet wheel 120 in the wheel well, yet readily removable from the ratchet recess 118 if necessary by later realigning the protrusion and groove. One could also envision using a cut-out in the surface which is alignable with the protrusion 132, with the protrusion then riding on the shoulder presented by the surface, once the wheel is rotated to place the protrusion out of alignment. The protrusion could also be a flexible finger, which is pressed inboard when the wheel is being emplace, and then springing outboard onto the shoulder presented by the surface.

When the ratchet wheel 120 is installed in the ratchet recess 118, the boss 134 extends into the aperture 126 of the ratchet wheel 120 and the protrusion 132 extends over the ledge 128 to prevent the ratchet wheel 120 from accidentally being removed from the ratchet recess 118.

To facilitate ease of assembly and disassembly, the ratchet wheel 120 may include an indicator 136 and the first plate 102 may include a corresponding indicator 138, that when aligned indicate that the cut-out is aligned with the protru-

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sion 132. This allows a use to visually identify the correct position of the ratchet wheel 120 with respect to the first plate 102 to install or remove the ratchet wheel 120 from the first plate 102.

The ratchet wheel 120 also includes a locking element capture receptacle 140 and an annular channel 142. The locking element capture receptacle 140 is configured to receive an end of the locking element 108 (illustrated in FIG. 1). The channel 142 is configured to receive and allow the locking element 108 (illustrated in FIG. 1) to be coiled around the ratchet wheel 120 to tighten the locking element 108 (illustrated in FIG. 1), as described in further detail hereinafter.

The ratchet wheel 120 may also include one or more tool engaging features 144, illustrated as oblong apertures. The tool engaging features 144 are configured to receive a corresponding male feature of a tool for use in rotating the ratchet wheel 120 to coil the locking element 108 (illustrated in FIG. 1) around the ratchet wheel 120.

In another embodiment, the ratchet wheel 120 may be shaped to be received in a drive receptacle of a tool. For example, referring to FIGS. 9 and 10, a top portion of ratchet wheel 120' may be configured to be received and engaged by a drive receptacle of a tool for use in rotating the ratchet wheel 120' to coil the locking element 108 around the ratchet wheel 120'.

Referring to FIG. 2, the first plate 102 includes a cut-out or area of reduced wall height 146 proximal to the face 116. This allows the locking element 108 (illustrated in FIG. 1) to extend from the first plate 102 and be coupled to the second plate 104, as described in further detail hereinafter.

The first plate 102 may include one or more shear pin receiving receptacles 148 in the face 116. The receiving receptacles 148 are configured to receive corresponding shear pins 110 (illustrated in FIG. 1) extending from the second plate 104. This assists in aligning the first and second plates 102 and 104 when the implantable fixation device 100 is installed and used. While pins are described to this end in this particular embodiment, other collateral engaging pieces or portions can be envisioned. Overlying flanges, tongue-and-groove mating parts, press-in spanning members and so forth could be applied. Pins are disclosed in this embodiment, as easily manipulated to snugly engage across the divide and between the two plate parts.

The first plate may also include one or more threaded fastener apertures configured to receive corresponding fasteners 150 to couple the first plate 102 to a bone or other body part. As illustrated in FIG. 2, the threaded fastener apertures include a first aperture 152a positioned proximal to the first end 112, a second aperture 152b positioned proximal to the second end 114, and a third aperture 152c in the boss 134. The apertures 152a-c may have a circular shape, oblique shape, or other shape, or a combination thereof. For example, the first and second apertures 152a and 152b may be oblique and the third aperture 152c may be circular. While there are three fasteners 150 and three corresponding threaded fastener apertures 152a-c, there may be more or less than three in the first plate 102 and the fasteners may be screws, pins, rivets, or other types of fasteners, etc.

Referring to FIG. 4, the second plate 104 includes a first end 154, a second end 156, and a second face 158 configured to be positioned facing the first face 116 of the first plate 102 (illustrated in FIG. 2) in an opposed relationship. Similar to the first plate 102, the second plate 104 may include one or more threaded fastener apertures configured to receive corresponding fasteners 150 to couple the second plate 104 to

a bone or other body part. As illustrated in FIG. 4, the threaded fastener apertures include a first aperture **160a** positioned proximal to the first end **154**, a second aperture **160b** positioned proximal to the second end **156**, and a third aperture **160c** substantially in a center of the second plate **104**. The apertures **160a-c** may have a circular shape, oblique shape, or other shape, or a combination thereof. For example, the first and second apertures **160a** and **160b** may be oblique and the third aperture **160c** may be circular. While there are three fasteners **150** and three corresponding threaded fastener apertures **160a-c**, there may be more or less than three in the second plate **104** and the fasteners may be screws, pins, rivets, or other types of fasteners, etc.

The second plate **104** may also include a locking element capture channel **162** formed in a top of the second plate **104** and extending across the second plate **104** in a substantially perpendicular direction to a longitudinal axis of the second plate **104**. The locking element capture channel **162** is configured to receive an end of the locking element **108** (illustrated in FIG. 1), as described in further detail hereinafter. The locking element capture channel **162** may also include a stop or ledge **164** configured to prevent the locking element **108** (illustrated in FIG. 1) from being pulled out of the channel in a direction of the face **158**.

As illustrated in FIG. 4, one or more apertures **166** extend through the second plate **104** in a substantially perpendicular direction to the longitudinal axis of the second plate **104**. The apertures **166** are configured to receive corresponding shear pins **110**. One aperture **166** may be positioned between the first aperture **160a** and the third aperture **160c**, and located to align with one of the receiving receptacles **148** of the first plate **102** (illustrated in FIG. 2). Another aperture **166** may be positioned between the second aperture **160b** and the third aperture **160c**, and located to align with the other of the receiving receptacles **148** of the first plate **102** (illustrated in FIG. 2).

The shear pins **110** may include deflectable prongs **168** and the second plate may include corresponding prong receiving receptacles configured to receive the prongs **168** to hold the shear pins **110** in the second plate **104**. As illustrated in FIGS. 1 and 4, the second plate **104** includes first prong receiving receptacles **170a** and second prong receiving receptacles **170b**. Each first prong receiving receptacle **170a** communicates with a corresponding one of the apertures **166**, and is located toward the entry point on the second plate. Similarly, each second prong receiving receptacle **170b** communicates with a corresponding one of the apertures **166**, and is located on the other side of the second plate.

Referring to FIGS. 4 and 7, the first prong receiving receptacles **170a** correspond to a first position of the shear pins **110** (as illustrated in FIG. 7). In the first position, the deflectable prongs **168** of the shear pins **110** are engaged with the first prong receiving receptacles **170a**. In this position, ends **172** of the shear pins **110** are positioned within the apertures **166** and do not extend past the face **158** of the second plate **104**.

Referring to FIGS. 4 and 5, the second prong receiving receptacles **170b** correspond to a second position of the shear pins **110** (as illustrated in FIG. 5). In the second position, the deflectable prongs **168** of the shear pins **110** are engaged with the second prong receiving receptacles **170b**. In this position, the ends **172** of the shear pins **110** extend past the face **158** of the second plate **104**, and extend into the receiving receptacles **148** in the face **116** of the first plate **102** (illustrated in FIG. 2) when the implantable fixation device **100** is installed and used to hold two corresponding bone portions together.

Referring to FIG. 5, the locking element **108** may be a bendable rod and have a first end **174** and a second end **176**. The first end **174** may include a first engagement portion that extends substantially perpendicular to a longitudinal axis of the locking element **108**. The first end **174** may be installed in the locking element capture receptacle **140** of the ratchet wheel **120**. The second end **176** may include a second engagement portion having a diameter greater than a remainder of the locking element **108**. The second end **176** may be installed in the locking element capture channel **162** of the second plate **104**. The locking element could take other forms, such as a sturdy wire or the like. Conceptually, it is an elongate member that is capable of being wound upon the ratchet wheel.

When the locking element **108** is installed and the ratchet wheel **120** is rotated, the locking element **108** is coiled around the ratchet wheel **120** to urge the first plate **102** and second plate **104** together and into alignment with one another. In this respect, the second end **176** may contact the stop or ledge **164** of the locking element capture channel **162** and allow the first plate **102** and second plate **104** to be pulled together.

The first plate **102** and second plate **104** may be configured to be used in conjunction with a fixation device positioning holder. Referring to FIGS. 6-8, the positioning holder **200** includes a body **202** including a first set of fastener guides **204a** and a second set of fastener guides **204b** on opposite sides of the body **202**, a compression attachment mechanism **206**, and attachment feet **208a** and **208b**. A version of a positioning holder is disclosed in U.S. Ser. No. 62/039,672, the disclosure of which is incorporated herein by reference, and to which priority is claimed. Note that the present invention is not to be limited to such a positioning holder, but could be emplaced using markings made by a template or the like for the fixation element locations.

The first and second sets of fastener guides **204a** and **204b** provide a housing to guide fasteners **150** for insertion into the threaded fastener apertures **152a-c** of the first plate **102** (illustrated in FIG. 2) and the threaded fastener apertures **160a-c** of the second plate **104** (illustrated in FIG. 4). Each of the first and second sets of fastener guides **204a** and **204b** may include cylindrical hollow tube like guide barrels that are positioned and oriented to align with the threaded fastener apertures **152a-c** of the first plate **102** (illustrated in FIG. 2) and the threaded fastener apertures **160a-c** of the second plate **104** (illustrated in FIG. 4). The positioning holder **200** may also be used to guide a driver and/or drill depending on the application, and/or to guide other instruments, for example, to place markings, pegs, headless pins, screws, etc. in a bone.

The compression attachment mechanism **206** may include a spring loaded mechanism that when compressed causes a distance between the attachment feet **208a** and **208b** to increase and when released causes the distance between the attachment feet **208a** and **208b** to decrease and mate with corresponding recesses **178** in the first plate **102** and corresponding recesses **180** in the second plate **104**.

The attachment feet **208a** and **208b** serve to hold the first and second plates **102** and **104** in the positioning holder **200** at a predetermined distance from each other. As illustrated in FIG. 7, the attachment feet **208a** and **208b** hold the first and second plates **102** and **104** in a coplanar arrangement, with the threaded fastener apertures **152a-c** of the first plate **102** (illustrated in FIG. 2) aligned with the respective guide barrels of the first set of fastener guides **204a** and the threaded fastener apertures **160a-c** of the second plate **104**

(illustrated in FIG. 4) aligned with the respective guide barrels of the second set of fastener guides **204b**.

The compression attachment mechanism **206** allows for the positioning holder **200** to be coupled to and uncoupled from the first and second plates **102** and **104** quickly and easily, simply by compressing the spring loaded mechanism. For example, when gripping portions **210a** and **210b** are compressed, the distance between the feet **208a** and **208b** is increased. This allows the first and second plates **102** and **104** to be placed in the positioning holder **200**, and when the compression force applied to the gripping portions **210a** and **210b** is released, the distance between the feet **208a** and **208b** decreases and the feet **208a** and **208b** mate with the recesses **178** and **180** of the first and second plates **102** and **104**, respectively.

The positioning holder **200** may include a handle **212** coupled to the fixation device **100** for ease of assembly of elements and placement of the plates (such as the plates **102** and **104**). The handle **212** may have an ergonomic design for comfort and control of the positioning holder **200**. The handle **212** may also be angled to accommodate soft tissues and various surgical approaches.

The positioning holder **200** may also include one or more spikes (not shown) extending from a bottom of the positioning holder **200** to assist in placing and holding the positioning holder **200** and the first and second plates **102** and **104** in a proper orientation as the fasteners **150** are driven to couple the first and second plates **102** and **104** to a bone or other portion of a patient's body.

In an embodiment, the first and second plates **102** and **104** may be used in a sternal resection procedure (or some other type of bone cut, where the bones are to be placed back into a desired juxtaposition). For example, referring to FIG. 9, soft tissue may be dissected from a surface of the sternum to allow for complete visualization of the bone, illustrated as block **902**. In addition to dissecting the soft tissue from the sternum, bony calluses, if present, may also be removed from the midline and sternal surface to allow for proper anatomical reduction and plate placement.

Referring to FIGS. 7 and 9, the first and second plates **102** and **104** may be loaded into the positioning holder **200**, and the fasteners **150** may be inserted into the first and second sets of fastener guides **204a** and **204b**, illustrated as block **904**. Referring to FIGS. 8 and 9, using the handle **212** the first and second plates **102** and **104** are positioned on a midline of a center of a sternum, illustrated as block **906**. Once the target position is achieved, gentle downward pressure on the positioning holder **200** may be applied to engage the periosteal spikes of the positioning holder **200** to stabilize the position of the first and second plates **102** and **104** on the sternum.

The fasteners **150** may then be driven into the bone of the sternum using a tool, such as a bone drill, illustrated as block **908**. It should be appreciated that if dense cortical bone is present, utilization of a pre-drilled hole may be advisable. Once the fasteners **150** are driven, the gripping portions **210a** and **210b** are compressed to disengage the attachment feet **208a** and **208b** from the first and second plates **102** and **104** and remove the positioning holder **200**, illustrated as block **908**. Depending on the length of resection, more than one implantable fixation device **100** may be installed by repeating the steps described herein.

Referring to FIGS. 9 and 10, sternal resection may then be performed. The first and second plates **102** and **104** are installed with a gap between the faces **116** and **158** of the respective first and second plates **102** and **104**. Additionally, the first and second plates **102** and **104** are initially installed

with the locking element **108** (illustrated in FIG. 5) removed, and the shear pins **110** are in the first position (i.e., the deflectable prongs **168** are engaged with the first prong receiving receptacles **170a**).

A cutting tool may be used to cut the sternum between the first and second plates **102** and **104**, using the first and second plates **102** and **104** as a guide, illustrated as block **910**. The sternum may then be retracted and a surgical procedure performed, illustrated as block **912**.

Referring to FIGS. 9 and 11, after the surgical procedure is complete, the first end **174** of the locking element **108** is seated in the locking element capture receptacle **140** of the ratchet wheel **120'**, illustrated as block **914**. The cut portions of the sternum may be reduced back together and the second end **176** is seated in the locking element capture channel **162** of the second plate **104**, illustrated as block **916**. The ratchet wheel **120'** is rotated and the locking element **108** is coiled around the ratchet wheel **120'** to urge the first plate **102** and second plate **104** together and into alignment with one another. The ratchet wheel **120'** or **120** may be rotated, for example, using tool **300** illustrated in FIG. 12. In an embodiment, the tool **300** includes a driving end **302** having male protrusions that engage the tool engaging features **144** of the ratchet wheel **120**.

Gross sternum reduction may be achieved using normal methods including manual external pressure, retraction instruments, wires, etc. Referring to FIG. 13, a reduction/alignment tool **400** may be used to bring the sternal edges into close apposition. As illustrated, the tool **400** includes plate engaging receptacles **402** configured to engage the first ends **112** and **154** or second ends **114** and **156** of the first and second plates **102** and **104**, respectively, to hold and align the first and second plates **102** and **104**. For example, the first ends **112** and **154** of the first and second plates **102** and **104**, respectively, into the plate engaging receptacles **402** and a medial force may be applied on the instrument to bring the sternal edges closer together.

Referring back to FIGS. 9 and 11, the shear pins **110** may also be deployed to the second position by pressing them into the second plate **104** in a direction of the first plate **102**, illustrated as block **918**. This causes the deflectable prongs **168** of the shear pins **110** to engage the second prong receiving receptacles **170b**. Referring to FIGS. 9 and 14, final approximation of the sternum is achieved by rotating the ratchet wheel **120** to cause the locking element **108** to be coiled around the ratchet wheel **120**. A series of audible clicks may occur as the ratchet wheel **120** is rotated. The sternal edges will be drawn closer into apposition with each click of the ratchet wheel **120**, illustrated as block **920**.

During the final approximation, it should be ensured that the shear pins **110** are aligned with the receiving receptacles **148** in the face **116** (illustrated in FIG. 2) of the first plate **102**, illustrated as block **920**. Use of the reduction/alignment tool **400** may be helpful in achieving alignment. As the first and second plates **102** and **104** are brought closer together, the shear pins **110** extend into the receiving receptacles **148** in the face **116** (illustrated in FIG. 2) of the first plate **102**. The receiving receptacles **148** may have a depth configured to allow the ends **172** (illustrated in FIG. 4) of the shear pins **110** to contact a bottom of the receiving receptacles **148** (illustrated in FIG. 2) to maintain the first and second plates **102** and **104** with the gap (described above) between them upon final approximation of the sternum. Note that in a preferred form, the shear pins do not "bottom" even if the plates were to touch, so as to ensure that the adjacent bone parts will contact one another.

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The steps described herein may be repeated for each implantable fixation device **100** that is used. When using multiple implantable fixation devices **100**, the procedure may be repeated by alternating reduction incrementally from implantable fixation device **100** to implantable fixation device **100** until complete closure is achieved. For example, referring to FIG. **15**, a middle implantable fixation device **100** may be incrementally tightened, a top implantable fixation device **100** may then be incrementally tightened, and then a bottom implantable fixation device **100** may be incrementally tightened. This may be repeated until the sternum is completely closed and the implantable fixation devices **100** are tightened together.

Once the implantable fixation device(s) **100** are tightened, the soft tissue may be closed in a normal fashion. It should be appreciated that sternal/cerclage wires may also be used in conjunction with the implantable fixation device(s) **100** if desired.

If emergency reentry is necessary, the fixation device(s) **100** allow for rapid access to the chest cavity. One option is to cut the locking element **108**. Referring to FIGS. **16-22**, the locking element **108** may be cut, for example using surgical scissors or other tool, illustrated as block **1602** and in FIG. **17**. The ratchet wheel **120** may then be rotated to align the indicator **136** on the ratchet wheel **120** and the indicator **138** on the first plate **102**, illustrated as block **1604** and in FIG. **18**. As described above, when the indicators **136** and **138** are aligned, the cut-out **130** is aligned with the protrusion **132** (illustrated in FIG. **2**). The ratchet wheel **120** may then be removed from the first plate **102**, along with the cut portion of the locking element **108** engaged with the ratchet wheel **102**, illustrated as block **1606** and in FIG. **19**.

The coiled portion of the cut locking element **108** may then be removed from the ratchet wheel **120** and discarded, along with the corresponding portion of the cut locking element **108** from the second plate **104**, illustrated as block **1608** and in FIG. **20**. The ratchet wheel **120** may then be reinstalled in the first plate **102** by aligning the indicators **136** and **138**, illustrated as block **1610** and in FIGS. **21** and **22**. The ratchet wheel **120** may then be rotated to allow a new locking element **108** to be installed, illustrated as block **1612**. The new locking element **108** may then be installed and the first and second plates **102** and **104** may be tightened to close the sternum as described above.

Another option is to remove the fasteners **150** and remove first and/or second plates **102** and **104** completely. If this option is used, the medial edges of the sternum may be brought into complete approximation using normal methods, including reduction instruments and or stainless steel wires. The first and second plates **102** and **104** may then be reinstalled with a new locking element **108** in accordance with the steps described above and illustrated in FIG. **9**.

Although the devices, systems, and methods have been described and illustrated in connection with certain embodiments, many variations and modifications should be evident to those skilled in the art and may be made without departing from the spirit and scope of the disclosure. For example, the components described herein may be made of titanium or other material suitable for surgical procedures. Other materials may also be used depending on the application of use. Similarly, the shapes, sizes, and dimensions of the components may be scaled up or down or altered to suit a particular application. The discourse is thus not to be limited to the precise details of methodology or construction set forth above as such variations and modification are intended to be included within the scope of the disclosure.

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What is claimed is:

1. A device for guiding separation of and rejoining opposed portions of a bone, comprising:
 - a first plate configured to be disposed on and coupled to the bone, the first plate including:
 - a first face;
 - a ratchet mechanism on a top portion of the first plate facing away from the bone; and
 - a first fastener aperture configured to receive a first fastener to couple the first plate to the bone;
 - a second plate configured to be disposed on and coupled to the bone, the second plate including:
 - a second face configured to oppose and face the first face when the first and second plates are coupled to the bone, and form a space between the first and second faces, the first and second faces are configured to guide a cutting tool through the space to create a divide in the bone between the first and second plates;
 - a second fastener aperture configured to receive a second fastener to couple the second plate to the bone; and
 - a pin aperture extending through the second plate in a substantially perpendicular direction to a longitudinal axis of the second plate;
 - a first prong receptacle communicating with the pin aperture and located distal to the second face;
 - a second prong receptacle communicating with the pin aperture and located proximal to the second face; and
 - a pin including a deflectable prong and configured to be inserted into the pin aperture, wherein the pin is in a first position in which an end of the pin is held within the pin aperture when the deflectable prong is engaged with the first prong receptacle, and the pin is in a second position in which the end of the pin extends beyond the second face when the deflectable prong is engaged with the second prong receptacle; and
 - a locking element engageable with the ratchet mechanism and the second plate, the locking element configured to be coiled in response to operation of the ratchet mechanism and draw the first and second plates together to close the divide.
 2. The device of claim 1, wherein the ratchet mechanism includes a ratchet recess in the top portion of the first plate and a ratchet wheel disposed in and removable from the ratchet recess.
 3. The device of claim 2, wherein the ratchet recess includes a plurality of teeth around a circumference of the ratchet recess that extend radially inward towards a center of the ratchet recess.
 4. The device of claim 3, wherein the ratchet wheel includes a pawl configured to engage the teeth and allow the ratchet wheel to rotate in a first direction while preventing rotation in an opposite direction.
 5. The device of claim 2, wherein the first plate includes a boss extending in an upward direction from a central portion of the ratchet recess, and a protrusion proximal to a top edge of the boss extending radially outward from a center of the boss, wherein the first fastener aperture extends through the boss.
 6. The device of claim 5, wherein the ratchet wheel includes:
 - a central aperture including a ledge extending substantially circumferentially around the central aperture and extending radially inward toward a center of the central aperture, the central aperture configured to receive the boss; and

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a cut-out in the ledge configured to allow the protrusion to pass through the central aperture when the cut-out and the protrusion are aligned, wherein the protrusion extends over the ledge when the ratchet wheel is disposed in the ratchet recess and the cut-out and the protrusion are misaligned.

7. The device of claim 1, wherein the first plate includes a pin receptacle in the first face configured to align with the pin aperture and receive the end of the pin when the first and second plate are coupled to the bone and the divide is closed.

8. The device of claim 7, wherein the pin receptacle has a depth configured to cause the end of the pin to contact a bottom of the pin receptacle when the divide is closed to maintain the first and second plates spaced the distance apart.

9. A device for guiding separation of and rejoining opposed portions of a bone, comprising:

a plate configured to be disposed on and coupled to the bone, the plate including:

a ratchet recess in a top portion of the plate facing away from the bone;

a boss extending in an upward direction from a central portion of the ratchet recess, and a protrusion proximal to a top edge of the boss extending radially outward from a center of the boss; and

a fastener aperture extending through the boss and configured to receive a fastener to couple the plate to the bone;

a ratchet wheel disposed in and removable from the ratchet recess; and

a locking element engageable with the ratchet wheel, the locking element configured to be coiled around the ratchet wheel in response to rotation of the ratchet wheel in a first direction.

10. The device of claim 9, wherein the ratchet recess includes a plurality of teeth around a circumference of the ratchet recess that extend radially inward towards a center of the ratchet recess.

11. The device of claim 10, wherein the ratchet wheel includes a pawl configured to engage the teeth and allow the ratchet wheel to rotate in the first direction while preventing rotation in an opposite direction.

12. The device of claim 9, wherein the ratchet wheel includes:

a central aperture including a ledge extending substantially circumferentially around the central aperture and extending radially inward toward a center of the central aperture, the central aperture configured to receive the boss; and

a cut-out in the ledge configured to allow the protrusion to pass through the central aperture when the cut-out and the protrusion are aligned, wherein the protrusion extends over the ledge when the ratchet wheel is disposed in the ratchet recess and the cut-out and the protrusion are misaligned.

13. A device for guiding separation of and rejoining opposed portions of a bone, comprising:

a plate configured to be disposed on and coupled to the bone, the plate including:

a fastener aperture configured to receive a fastener to couple the plate to the bone;

a capture channel formed in a top portion of the plate facing away from the bone, wherein the capture channel extends across the plate in a substantially perpendicular direction to a longitudinal axis of the plate;

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a pin aperture extending through the plate in a substantially perpendicular direction to the longitudinal axis of the plate;

a first prong receptacle communicating with the pin aperture and located distal to a face of the plate; and

a second prong receptacle communicating with the pin aperture and located proximal to the face;

a pin configured to be inserted into the pin aperture, the pin including a deflectable prong, wherein the pin is in a first position in which an end of the pin is held within the pin aperture when the deflectable prong is engaged with the first prong receptacle, and wherein the pin is in a second position in which the end of the pin extends beyond the second face when the deflectable prong is engaged with the second prong receptacle; and

a locking element engageable with and configured to be captured in the capture channel.

14. The device of claim 13, wherein the capture channel includes a stop configured to prevent the locking element from being pulled through the capture channel in a direction substantially perpendicular to the longitudinal axis of the plate.

15. The device of claim 14, wherein the locking element includes an end having an engagement portion with a diameter greater than a remainder of the locking element, wherein the engagement portion is configured to engage the stop.

16. A sternal closure apparatus for rejoining opposed parts for rejoining opposed parts of a resected sternum, comprising:

a first plate member and a second plate member which engage with each other along a divide between said plate members, said plate members each having a bottom (body facing) side and a top (outward facing) side;

a ratchet mechanism on said first plate member;

joinder bars mounted for movement on one of said plate members and receiving receptacles for receiving a portion of each said joinder bar on the other of said plate members, said joinder bars being spaced apart along said divide;

openings defined in each of said plate members extending through said top and bottom sides for receiving bone fixation elements;

bone fixation elements receivable in said openings having fixation portions which engage said plate members to fix said plate members in place on an underlying bone part;

said ratchet mechanism having a wheel rotating on an axis with a pawl formed on said wheel that interacts with a ratchet element, and a locking element capture receptacle being formed on said wheel;

a bendable elongated locking element having one end received in said locking element capture receptacle, and another end having a stop formed thereon, said stop being received in a notch formed in said second plate member, said locking element spanning said divide;

said ratchet mechanism with said locking element received in said locking element capture receptacle causing said locking element to wrap about said wheel as said wheel is rotated advancing said pawl against said ratchet element, and thereby engaging said stop in said notch and drawing said plate members into relative engagement as said ratchet mechanism is advanced.

17. An apparatus for joining opposed parts of a bone or other body portion, comprising:

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- a first joinder member and a second joinder member which are attachable to a bone or other body portion along a divide which said joinder members are intended to reduce or close, said joinder members each having a bottom (body facing) side and a top (outward facing) side;
- a ratchet mechanism on said first joinder member, wherein said ratchet mechanism includes a wheel rotatable on an axis and a pawl formed on said wheel that interacts with a ratchet element, and a locking element capture receptacle formed on said wheel;
- openings defined in each of said joinder members extending through said top and bottom sides for receiving fixation elements for anchoring each said joinder member to an underlying bone or body portion;
- fixation elements receivable in said openings having fixation portions which engage said joinder members to fix said joinder members in place;
- a bendable elongated locking element having one end received by said locking element capture receptacle, and another end attached to said second joinder member, said locking element spanning said divide;
- said ratchet mechanism with said locking element received by said locking element capture receptacle causing said locking element to wrap about said wheel as said wheel is rotated, and thereby drawing said joinder members into relative engagement as said ratchet mechanism is advanced.
18. The apparatus of claim 17, further including at least one stabilizing element having a part on one joinder member which interfits with another part on the other joinder member, said stabilizing element spanning said divide.
19. The apparatus of claim 18, wherein there are at least two said stabilizing elements, said stabilizing elements comprising joinder bars mounted for movement on one of said joinder members and receiving receptacles for receiving a portion of each said joinder bar on the other of said joinder members, said joinder bars being spaced apart along said divide.
20. The apparatus of claim 17, wherein said joinder members are each in the form of plates having generally planar tops and bottoms.
21. An apparatus for joining opposed parts of a bone or other body portion, comprising:
- a first joinder member and a second joinder member which are attachable to a bone or other body portion along a divide which said joinder members are intended to reduce or close, said joinder members each having a bottom (body facing) side and a top (outward facing) side;

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- openings defined in each of said joinder members extending through said top and bottom sides for receiving fixation elements for anchoring each said joinder member to an underlying bone or body portion;
- fixation elements receivable in said openings having fixation portions which engage said joinder members to fix said joinder members in place;
- said joinder members being fixable in position on said bone or body portion with a space separating said joinder members, said space adapted to permit a surgical cutting tool to pass through said space and cut the underlying bone or body portion to create said divide;
- a stabilizing element coupled to one joinder member and movable between a retracted position and an extended position, wherein the stabilizing element is retracted into said one joinder member when in the retracted position, and an end of the stabilizing element extends from said one joinder member and spans said divide with the end interfitting with the other joinder member when in the extended position; and
- a mechanism which engages said joinder members across said divide to reduce or close said divide.
22. The apparatus of claim 21, wherein said mechanism is a winding mechanism on said first joinder member having a rotary piece and an anchor point being formed on said rotary piece;
- a bendable elongated locking element having one end received by said anchor point, and another end attached to said second joinder member, said locking element spanning said divide;
- said winding mechanism with said locking element received by said anchor point causing said locking element to wrap about said rotary piece as said rotary piece is rotated, and thereby drawing said joinder members into relative engagement as said winding mechanism is advanced.
23. The apparatus of claim 22, wherein said winding mechanism comprises a wheel rotating on an axis with a pawl formed on said wheel that interacts with a ratchet element, and a locking element capture receptacle being formed on said wheel as said anchor point.
24. The apparatus of claim 21, wherein the stabilizing element includes at least two said stabilizing elements, said stabilizing elements comprising joinder bars mounted for movement on one of said joinder members and receiving receptacles for receiving a portion of each said joinder bar on the other of said joinder members, said joinder bars being spaced apart along said divide.

* * * * *

UNITED STATES PATENT AND TRADEMARK OFFICE
CERTIFICATE OF CORRECTION

PATENT NO. : 10,441,329 B2
APPLICATION NO. : 14/524922
DATED : October 15, 2019
INVENTOR(S) : May et al.

Page 1 of 1

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

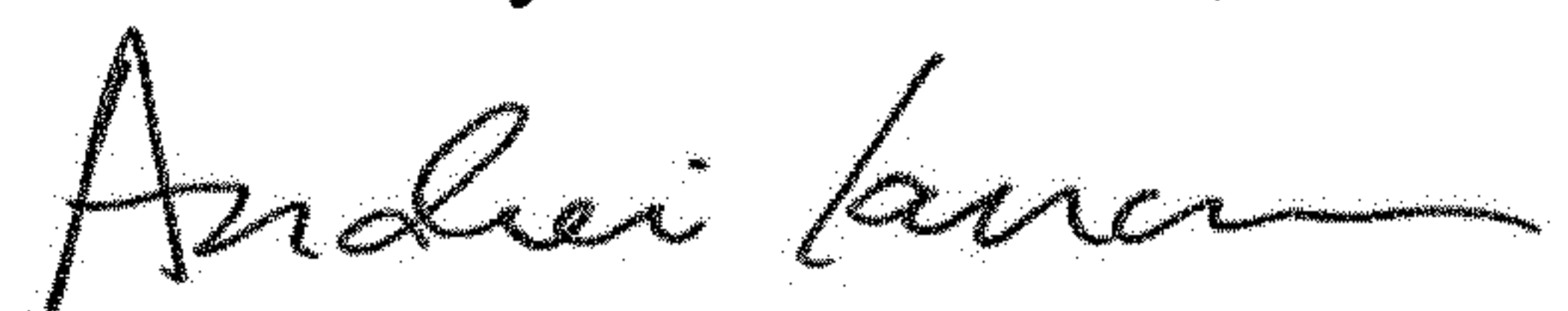
On the Title Page

In Column 2, Item (56) immediately before “Primary Examiner - Si Ming Ku”, please insert:

--OTHER PUBLICATIONS

International Search Report for PCT/US2014/062441 dated March 25, 2015.--.

Signed and Sealed this
Third Day of November, 2020



Andrei Iancu
Director of the United States Patent and Trademark Office